REPORT OF INVESTIGATION NO. 9 1951

STATE OF ILLINOIS

AOLAI E. STEVENSON, Governor

THE SILTING OF CARBONDALE RESERVOIR

Carbondale, Illinois

B.O. Larson, A.A.Kingebiel, E. L. Sauer
S.W. Melsted and R.C. Hay

Illinois State Water Survey Division, Soil Conservation Service
United States Department of Agriculture, and Illinois
Agricultural Experiment Station, With local
aid from the City of Carbondale

DEPARTMENT OF REGISTRATION AND EDUCATION

NOBLE J. PUFFER, Director

STATE WATER SURVEY DIVISION

A.M.BUSWELL, Chief

URBANA, ILLINOIS

(Printed b> authority of State of Illinois)

STATE OF ILLINOIS

AOLAI E. STEVENSON, Governor

THE SILTING OF CARBONDALE RESERVOIR

Carbondale, Illinois

B.O. Larson, A.A.Klingebiel, E. L. Souer
S.W. Melsted and R.C. Hay

Illinois **State Water Survey Division, Soil Conservation Service United States Department of Agriculture, and Illinois Agricultural Experiment Station, With local aid from the City of Carbondale**

DEPARTMENT OF REGISTRATION AND EDUCATION

NOBLE J. PUFFER, Director

STATE WATER SURVEY DIVISION

A.M.BUSWELL, Chief

URBANA, ILLINOIS

(Printed **by authority of State** ***of Illinois)***

CONTENTS

WATERSHED

REMEDIAL MEASURES

SUMMARY

1. Carbondale Reservoir, the municipal water supply reservoir at Carbondale, Illinois, was built in 1926. The lake has a drainage area of 3. 1 square miles; original reservoir surface area was 144 acres and volume was 1386 acre-feet.

2. The 1948 sedimentation survey of the reservoir shows a capacity loss of 0.63 per cent per year. In 22. 1 years the lake has lost 13. 9 per cent of original capacity.

3. Serious drawdowns have occurred on this reservoir in several years since construction. During the droughts of 1930 and 1940, the reservoir was emptied by the city pumpage and water shortages were experienced.

4. During the water shortage of 1940 a 4-mile pipeline was laid to Crab Orchard Lake, a large government-owned reservoir nearby. The government allows the city to pump from Crab Orchard Lake during emergencies. The city pays 2 cents per 1000 gallons for this raw water.

5. In 1949 the city consumption amounted to 109 gallons per capita per day.

6. Present city pumpage is 1.4 million gallons per day. If Carbondale continues to grow as other comparable Illinois cities have in the past, the population served by the water system will reach 17,000 by 1970. Total pumpage at that date will then average nearly 2 million gallons per day.

7. A deficiency in rainfall of 10 inches or more from the average in any year will probably result in a water shortage at Carbondale. Such deficiencies in 1940, 194i, and 1942 necessitated the use of water from Crab Orchard Lake. Shortages of increasing severity can be expected in future years.

8. The deficiency of supply at Carbondale is not primarily due to loss of reservoir capacity to sediment but rather to inadequate total storage to meet the increasing water needs of the city.

9. Chemical analyses of samples of the reservoir sediment show lower values of organic carbon and nitrogen than found in other reservoirs of the state. This and other evidence suggest that much of the fine clay and collodial material entering the lake is passed on through the lake over the spillway.

10. The density of the sediment deposits varies from 39. 7 to 85. 5 pounds per cubic foot.

11. The lake sediment physical and chemical composition is very similar to that of the predominant surface soils of the watershed.

12. Soils of the Ava silt loam group occupy 73. 3 per cent of the watershed area. These soils are generally very slowly permeable and highly erosive when cultivated.

13. Of the total watershed area, 63. 1 per cent has a slope exceeding 7 per cent and 44. 3 per cent of the area has a slope exceeding 12 per cent.

14. Only 31.3 per cent of the watershed area is classified in land capability classes I, II, and III, which are considered safe for continuous cultivation. Of this percentage 14.5 per cent is in class III which can be cultivated only with intensive conservation practices to reduce soil losses.

15. Of the present land cropped, 31.9 per cent is located on land classified as VI and VII, which is not recommended for any cultivation.

16. Erosion classified as "severe" and "very severe" is occurring on 46. 7 per cent of the watershed area, while 1. 3 per cent of the area is considered "destroyed land. "

17. To reduce soil losses in the watershed, major changes in land use are needed; 250 acres of present cropland should be retired, while 170 acres of present idle land could be cultivated with some conservation measures.

18. Under present management, the soil loss from the watershed is approximately 21,242 tons per year. This loss could be reduced to 1, 750 tons per year if the land were farmed in accordance with its capabilities. Soil treatment, pasture reseeding, contour farming, terracing, changes in cropping practice, and other measures are recommended to bring about this reduction.

19. The Jackson County Soil Conservation District was organized in 1944 by the farmers of the county, to promote the application of soil conservation practices to the lands of the county.

20. The expected industrial development of the Crab Orchard Lake area will cause increased industrial pumpage from Crab Orchard Lake. The dependence of the City of Carbondale on this lake for supply during the critical drought periods

could likely put the city in competition with industry for the water in the lake.

21. The water supply of the entire region is closely related. A water supply sufficient to meet the increasing needs of the City of Carbondale independent of Crab Orchard Lake is needed to allow for the reasonably expected economic development of the entire region.

22. A new reservoir couldbe built on Indian Creek to store 2690 acre-feet, or on Sycamore Creek to store 3160 acre-feet.

23. The present Carbondale Reservoir, although inadequate, is worth preserving. It will probably continue to be the major source of supply in conjunction with any other supply decided upon. For this reason, a watershed protection program is suggested. Such a program should also be included in plans for future reservoirs.

24. Conservation measures needed to reduce soil losses on this watershed are profitable to the individual farmers by increasing income.

25. Based on 1945 costs, it would cost $22.63 per acre to establish the needed conservation program on the Carbondale Reservoir watershed. Four years of increased income that would result from application of a conservation program would repay this complete cost plus interest. In addition, the capital resources of the farm would be built up.

26. It is recommended that the City of Carbondale make provisions now for an adequate municipal water supply independent of Crab Orchard Lake, in order that the industrial and economic development of the city and region can proceed without hindrance.

27. It is recommended that the City of Carbondale immediately sponsor the development of a soil and water conservation program on the Carbondale Reservoir watershed in order to prolong the ultimate life of this reservoir and the length of time it can be used as part of the public supply. This program should be carried out in cooperation with the Jackson County Soil Conservation District, other agricultural agencies, and in accordance with the foregoing report.

28. It is recommended that the City of Carbondale purchase the watershed areas which are critical to erosion control, or else assume the major financial responsibility in the application of the needed conservation measures to these areas. In the latter case, financial assistance to present landowners would be contingent upon the landowners' agreement to maintain such conservation measures.

THE SILT PROBLEM AT CARBONDALE RESERVOIR
CARBONDALE, ILLINOIS

by

B. O. Larson, Associate Engineer, Illinois State Water Survey Division, Urbana, Illinois

A. A. Klingebiel, State Soil Scientist, Soil Conservation Service, Urbana, Illinois

E. L. Sauer, Project Supervisor, Research, Economics of Soil Conservation, Soil Conservation Service and Illinois Agricultural Experiment Station Cooperating, Urbana, Illinois

S. W. Melsted, Associate Professor of Soil Analysis Research, Agronomy Department, College of Agriculture and Agricultural Experiment Station, University of Illinois, Urbana, Illinois

R. C. Hay, Associate Professor of Soil Conservation, Agricultural Engineering Department, University of Illinois, Urbana, Illinois

INTRODUCTION

OBJECTIVES OF STATE-WIDE PROGRAM

Precipitation gives us our surface water supplies, in that a portion of it finds its way to the lakes and streams. Since streams sometimes dry up or have a low flow due to lack of precipitation, man has constructed impounding reservoirs, the purpose being the "equalization of water supply by storing the large flows of wet season for release during periods of drought and low run-off."

Need for Data

To date there are some 500 lakes and reservoirs in the State of Illinois and a study of the State has been made[2] which shows that there still remain 600 sites where suitable reservoirs can be built economically to furnish a supply of water for various purposes.

Many of the present impounding reservoirs in Illinois have been designed and built in the past 30 years. In the design of reservoirs, "engineers usually selected the most favorable sites for these reservoirs considering such factors as distance from the city, dam foundation conditions, water yield from the watershed, peak rates of run-off, population trends, cost of storage furnished,"[3] and quantity of supply required.

In the design of a reservoir to be used as a source of supply for municipal use, an allowance of reserve storage space is usually provided for increased consumption due to population increase, changes in requirements of existing industrial users, and to meet the demands of probable new industries. "The sedimentation factor was not considered because it was not generally recognized, or, if so, data on rates of sediment production necessary for design purposes were lacking."[3]

The erosion of lands has long been recognized and certain corrective measures have been taken to keep the soil in place. One example of this is the construction of the rice paddy in China to keep both the fertile soil and required amounts of water where desired. The menace of sediment, although long recognized, has not been well understood. It has been thought that erosion occurred primarily on steep lands; however, recent studies indicate that this is not necessarily true. In Illinois a considerable amount of the sediment that is found in streams comes from sheet erosion of gently sloping lands used for production of intertilled crops. As more land has become "improved" and used for grazing, tillage, grass, and cultivation, more erosion has taken place, and a greater amount of

1. Brown, C. B., The Control of Reservoir Silting, Miscellaneous Publication No. 521, U. S. Department of Agriculture, p. 2.

2. Preliminary Data on Surface Water, Illinois State Water Survey Bulletin No. 31, 157 pp., Urbana, Illinois, 1937.

3. "The Silt Problem at Spring Lake, Macomb, Illinois," Report of Investigation No. 4, 1949. State Water Survey.

sediment has found its way to the streams. Due to erosion the top soil is removed from the land; the lands become less productive and eventually become almost worthless. Some of this sediment enters streams on which water supply reservoirs have been built to furnish a municipal supply. If erosion of the land is great, the sediment load carried by the stream is large. A portion of the sediment is deposited in the stream channel and impounding reservoirs. As the reservoirs become filled with the sediment, the ability to store water is reduced, and if the loss of capacity due to sedimentation is high, the reservoir may rapidly approach uselessness. An example of this is Spring Lake, a reservoir which furnishes the municipal supply for Macomb, Illinois. In the 20 years that Spring Lake was in existence before a sediment survey was made, the reservoir had lost 47. 3% of its original capacity due to sediment deposits. Since storage capacity is decreasing and Macomb's water demand is increasing, by 1953 the reservoir will be inadequate to furnish the needs in the event of a severe drought. [4]

Sediment not only reduces the capacity of a reservoir, but concentrations of turbidity in reservoirs and rivers make the water undesirable for use in industrial processes. Turbid waters make for greater expense in the filtering and treatment for various uses. Survival of desirable species of game fish is affected, and navigation in streams is retarded, requiring expensive dredging operations to keep the stream channels open.

Illinois Program

Because of the seriousness of erosion and the subsequent rapid reservoir sedimentation together with the lack of suitable quantitative data relative to the problem, the Illinois State Water Survey, the Illinois Agricultural Experiment Station and the Soil Conservation Service in 1936 joined in a cooperative study in an effort to collect the desired data. It was desired to determine the effects of different watershed and climatic factors on the rate of sediment production and the rate of sedimentation of reservoirs. The sedimentation survey of Carbondale reservoir was made under this program.

At present, sedimentation data are available on 33 Illinois reservoirs. Detailed surveys of 14 reservoirs have been made, and four of these have been resurveyed, after an elapsed period of 10 years or more, to determine the change in rate of sedimentation where this occurs. Reconnaissance surveys of 8 additional reservoirs have been made, the purpose of which is to obtain with a minimum of field effort, a maximum of data on rates of sediment production and rates of erosion. Miscellaneous data have been collected from five others by observation rather than by the approved survey methods. Preliminary cross - sections have been established on five new state - owned conservation lakes in Illinois. Future surveys of these established cross-sections will furnish data as to the amount of sediment that has been deposited on the floor of the reservoir during the elapsed period of time.

Orientation

The southern two-thirds of the State depends primarily on surface water for supply, whereas the northern one-third is generally dependent on ground-water sources. In the "surface water resources" area 110 communities are not adequately served by a public water supply. Ground water in this area is generally not adequate for municipal supplies. Therefore any future water supply developments would normally include the construction of impounding reservoirs.

In classifying areas for study, the physiographic divisions and boundaries of soils of the State were considered. This makes it possible to compare results of data collected under many varying conditions of soils and physiography within the State.

Reservoir sites must be considered as natural resources and everything should be done to preventthe waste of these sites due to high rates of siltation. It is desirable to establish information on all factors that affect sedimentation. There is definitely a need for a more complete understanding of the sedimentation problem by everyone concerned; by the public who will authorize funds for the construction of future reservoirs, by the engineer who will be designing and building them, and by the farmer who will profit by having his top soil retained on the land.

Need for This Report

This survey and report of the Carbondale reservoir are a part of the state-wide program. This reservoir is representative of one having a small watershed and a high Capacity-Watershed ratio. The land is light-colored, upland timber soil that is slowly permeable. Primarily, this report is made to investigate the effects of silting on the adequacy of the Carbondale reservoir as a source for the municipal water supply.

Inasmuch as the State Water Survey had been collecting and compiling data on Carbondale Reservoir relative to precipitation, run-off, discharge, storage, and pumpage since 1930, it seemed advantageous to complete the study by obtaining data relative to the rate of sedimentation in the reservoir. The city officials of Carbondale were receptive to this program and agreedto render any assistance that was deemed necessary.

4. "The Silt Problem at Spring Lake." op. cit.

SCOPE OF INVESTIGATIONS

Lake Survey

A detailed sedimentation survey of the reservoir was made from June 18-20, and July 12-16, 1947. Soundings were rechecked September 2-3, 1948. The work was carried out by a field party of the State Water Survey Division, the Soil Conservation Service, and the City of Carbondale. The water depths and sediment thicknesses in the reservoir were measured along fifteen silt ranges. The survey determined the original capacity of the reservoir, the present capacity, and consequently, the volume of sediment in the reservoir. The surface area was measured by mapping the present shoreline. It was decided that the original and present shorelines were the same. In carrying out the survey a permanent marking system was installed so that in the future, resurveys may be made to measure the sediment accumulation at that time.

An analysis of the past trend in water consumption as well as possible future water requirements of the City of Carbondale has been made by the State Water Survey. It is shown in this report that the original capacity of the reservoir was inadequate to furnish the water required by the city in case of a severe drought.

Watershed Survey

Factors affecting the rate of sedimentation of reservoirs include size of drainage area, topography, soil types, slopes and land use. The relative importance of these factors must be examined in order to develop reservoir design data. In addition, the source of sediment must be determined if an effective silt control program is to be developed. As a part of this study, the Soil Conservation Service has made a conservation survey of the soils of the Carbondale Reservoir and a study of land use. The conservation survey consisted of field mapping of soil groups, slopes, degree of erosion and present land use on aerial photographs having a scale of 4 inches to one mile.

Sediment Samples

During the course of the survey a series of 13 sediment samples was taken from various parts of the reservoir by means of a special sampler. Chemical and physical analyses of these samples have been made by the Illinois Agricultural Experiment Station. An analysis of the texture, colloidal content, volume, weight, and plant food constituents of the sediment was made to learn, if possible, the watershed sources of the sediment deposited in the reservoir.

Interpretation of Results

The final interpretation of the silting problem at Lake Carbondale has been made on the basis of the complete reservoir and watershed data by the three cooperating agencies. Results are presented so as to be most helpful to reservoir owners. Although the rate of storage depletion of the reservoir is not great, remedial measures to reduce this rate by the application of a complete watershed protective program are discussed. Inasmuch as the capacity of the present reservoir has already been proven inadequate in years of severe drought, two additional reservoir sites and other remedial measures are discussed.

ACKNOWLEDGEMENT

City of Carbondale

The agencies conducting this survey wish to acknowledge the generous cooperation of the municipal authorities of Carbondale, particularly Mr. Ray Borger, the City Water Commissioner, Mr. Clifford Fore, then Water Superintendent, and Mr. Jesse Fly, present Water Superintendent, who were very helpful. Two boats were supplied by the city for the survey. One helper was furnished by the city for the conduct of the field work.

State Water Survey Division

The survey of Carbondale Reservoir was made by a field party of the Engineering Subdivision, consisting of the following men in 1947: Bernt O. Larson, Chief of the Party; John B. Stall, Assistant Engineer; Leslie Jones; and Douglas Rucker. In 1948 additional work was done by John B. Stall and Thomas E. Young. This Division made the computations on the results of the reservoir survey including the water and sediment volumes. The engineering section of this report was prepared by Bernt O. Larson. The entire report was prepared by Mr. Larson and edited by Mr. Stall, under the supervision of Mr. H. E. Hudson, Jr., Head of the Engineering Subdivision.

Soil Conservation Service

The Soil Conservation Service of the United States Department of Agriculture has participated in the Illinois sedimentation program in many different ways. The sedimentation section of the Office of Research in Washington furnished the specialized field equipment for the survey work. Mr. L. C. Gottschalk, Head of the Sedimentation Section, gave technical assistance during two weeks spent with the survey party at the beginning of the summer's work in 1947 and reviewed the present report.

Mr. B. B. Clark, State Conservationist, cooperated by authorizing the conservation survey of this watershed by Soil Conservation Service personnel and cooperated with the authors in the compilation of this report. The field work of the watershed survey was carried out by Mr. George Walker, Soil Scientist, during 1947 under the supervision of Mr. A. A. Klingebiel, State Soil Scientist.

In the conduct of the agricultural phases of this study Mr. S. R. Golden, District Conservationist of the U. S. Soil Conservation in 1947, and Mr. Charles T. Hufford, Work Unit Conservationist of Jackson County, have been most helpful.

Dr. E. L. Sauer, Project Supervisor, Research Economics of Soil Conservation, Soil Conservation Service and Illinois Agricultural Experiment Station cooperating, carried out the study of land use and conservation history of the watershed. This study entailed both field visits and study of public records and their interpretation. Dr. Sauer also prepared the data in this report concerning the costs and benefits of conservation.

Soil Conservation Districts

The Jackson County Soil Conservation District has cooperated by authorizing the use of personnel assigned to the District for carrying out the conservation survey of this watershed.

The Illinois State Soil Conservation Districts Board cooperated in this study by financing the laboratory work in making the sediment analysis. This work was carried out in the laboratories of the Illinois Agricultural Experiment Station.

Illinois Agricultural Experiment Station

Samples of the sediment in the lake were procured by the field party. Under the supervision of E. E. DeTurk, Professor of Soil Fertility, these samples were analyzed in detail in the laboratory of the Agricultural Experiment Station. The interpretation of these analyses and their comparison to watershed soils has been carried out by S. W. Melsted, Associate Professor of Soil Analysis. Mr. Melsted also compiled the section of the report interpreting the analytical results.

Professor R. C. Hay, Agricultural Engineering Department, with the assistance of A. A. Klingebiel, Soil Conservation Service, compiled the watershed section of this report, including the recommended watershed conservation program.

RESERVOIR

GENERAL INFORMATION

Dam

The dam has a total length of approximately 2800 feet and is located in the N.W. 1/4 of Section 33, T. 9S., R. 1 W. The dam extends approximately 1400 feet east from the N.W. corner of Section 33, and thence southeastward approximately another 1400 feet, as shown in Figure 2. The top of the dam is at elevation approximately 442 feet above mean sea level and is 12 feet in width. The dam is earthen construction with a 3 to 1 slope on the upstream face and a 2 to 1 slope on the downstream face. Design specifications indicated a puddled clay core a minimum of 6 feet in width extending to hardpan. A belt of broken rock riprap was placed on the upstream face of the dam to protect it from erosion.

Spillway

The spillway is located at the extreme southeast end of the dam. The crest is 100 feet in width and has an elevation of 437.03 feet. The details of the spillway crest as well as the outlet channel below the spillway are shown in Figure 3.

Reservoir

The reservoir is located approximately two miles south of Carbondale City Hall in Sections 33 and 32 of Township 9 S., Range 1 W. The reservoir is formed on Piles Fork which flows thence northward four miles to empty into Crab Orchard Creek just northeast of the City. Crab Orchard Creek flows northward, emptying into the Big Muddy River in the east central part of Jackson County. The lake was constructed in 1926; thus at the date of the 1948 survey it had been in existence about 22 years. For this period it has been the primary source of raw water supply for the City of Carbondale as discussed later in this report. Water flows through a 16-inch cast iron pipe from the intake tower at the dam to the city filter plant in Carbondale as shown in Figure 2.

In addition to furnishing the public water supply, the lake is used for recreation. Park facilities have been provided by the city and extend along most of the northern shore of the lake.

The lake is generally oval in shape, being approximately 4500 feet long and varying in width from 1000 to 1400 feet. There is one major side arm on the south. The original depth of water at the dam above the valley floor was approximately 20 feet. The pre-reservoir creek chan-

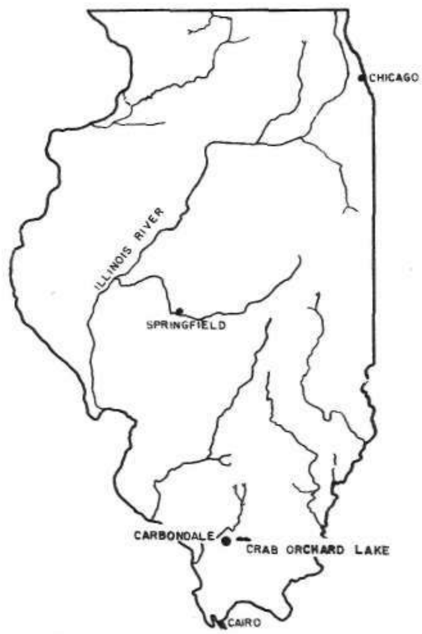

Figure 1. Carbondale area location map.

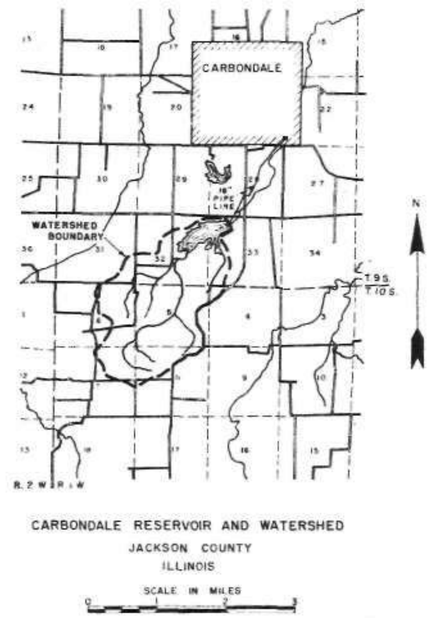

Figure 2. Carbondale reservoir location map.

nel was incised into the flood plain about five feet, making the total original water depth in the creek channel originally about 25 feet.

Watershed

The watershed is oval in shape and is drained by two main branches of Piles Fork as showr in Figure 2. The watershed extends generally south and west of the reservoir with its highest point and elevation approximately 600 feet above mean sea level. The two main branches of the stream flow generally north and unite near the head of the reservoir.

METHODS OF SURVEY

The original and present storage capacities and silt volumes of the reservoir were determined by the range method of survey developed by the Soil Conservation Service anddescribed in their Bulletin No. 524, "Silting of Reservoirs."[5]

5. Eakin, H. M., Silting of Reservoirs, U. S. Department of Agriculture Technical Bulletin No. 524, revisea by C. B. Brown, 168 pp., illustrated, Washington, D. C., U. S. Government Printing Office 1939.

Range System

A baseline 830 feet in length was laid out alongthe northwest-southeast portion of the dam fill. From this a triangulation network consisting of 10 stations was expanded. This network served as control for mapping the entire shoreline and for the establishment of the silt ranges. The shoreline mapping was done with a plane-table and telescopic alidade to a scale of 1 inch to 200 feet. After mapping the shoreline a system of 15 silt ranges was established as shown in Figure 4.

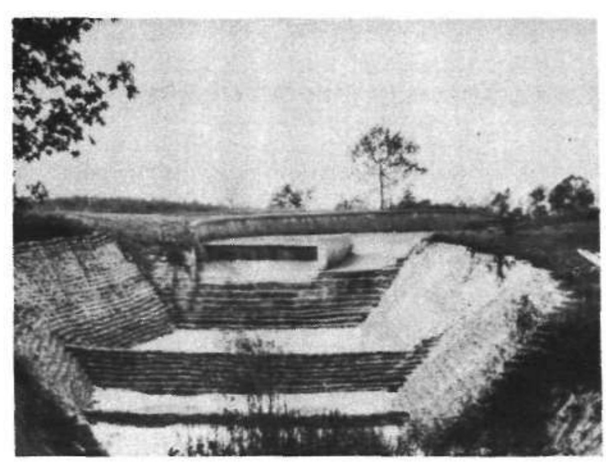

Figure 3. Reservoir spillway and outlet channel.

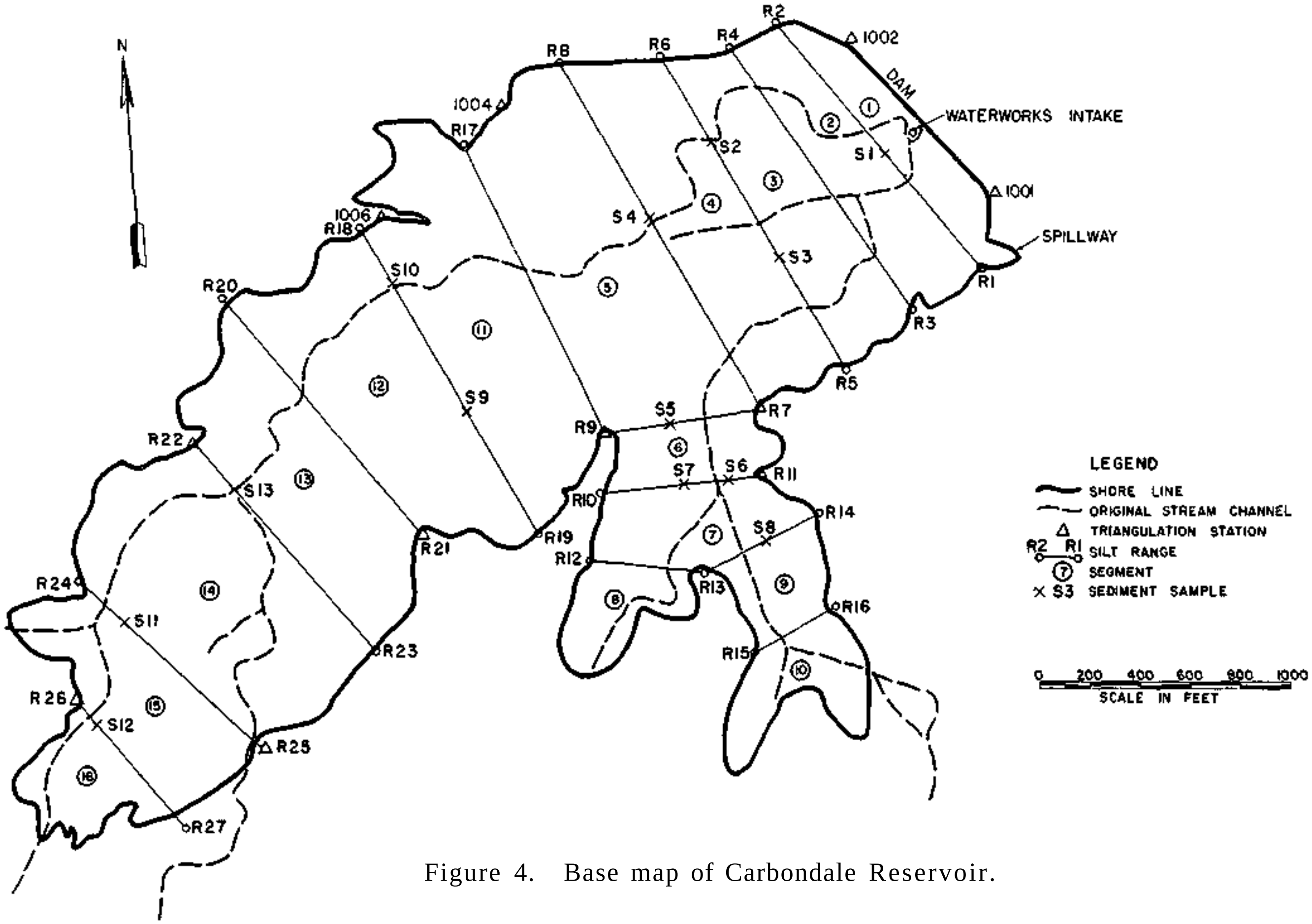

Figure 4. Base map of Carbondale Reservoir.

Measurement of Silt

Along each silt range at intervals of 25 feet the water depth and silt thickness were measured with a sounding pole. This consists of a 1 1/4 inch diameter calibrated wooden pole constructed in sections to give a total length of 25 feet. This pole is shown in use in Figure 5. The pole is lowered into the water until it strikes the top of the silt deposit and thus the present water depth is measured. The pole is then thrust on down through the soft silt until it strikes the hard soil of the original reservoir bottom. In this manner the present water depth and the silt thickness are measured. As the boat is rowed across the range, a cross-section of water depth and silt thickness is obtained. A total of 437 silt measurements were made on 15 ranges on the Carbondale Reservoir.

Survey Markers

All triangulation station and range ends were marked permanently in the field with concrete posts 4 1/2 inches square and 4 1/2 feet long. As shown in Figure 6, these posts were set into the ground with about *1* foot exposed. The posts were painted white and identification numbers were painted on in black. This permanent marking system will be of value in the future when it becomes desirable to relocate the present silt ranges to make a resurvey of Carbondale Reservoir along these same ranges.

Prior Surveys

In the summer of 1930 the water level in the reservoir dropped to a point approximately 15 feet below the spillway crest. (See Figure 7.)

Figure 5. Use of the sounding pole in measuring sediment.

Figure 6. Permanent survey marker.

The officials of the Illinois Central Railroad, one of the largest industrial consumers at Carbondale, became somewhat coccerned for fear that the reservoir would not be able to supply their complete needs. As a result, the railroad sent a surveying party to the reservoir to obtain enough data to make an estimate of the quantity of water remaining in the reservoir as well as the complete storage capacity of the reservoir. At that time a contour map of the dry portion of the reservoir basin was made. This showed the total capacity of the reservoir to be 392 million gallons.

In the summer of 1941, the water level in the reservoir reached the stage 13.65 feet below spillway crest. At this time a survey party of the State Water Survey in cooperation with the Carbondale Waterworks officials conducted a topographic survey of the dry portion of the reservoir bed. The total capacity of the reservoir at this time was found to be 356 million gallons. The comparison of this figure to the volume found by the 1930 survey of 392 million gallons shows a loss of capacity of 9.2%. This is a loss of almost 1% per year, which is comparable to the data found in the current survey. The absolute volume of the reservoir as found by these two contour surveys was not believed to be sufficiently accurate for comparison to the original and present volumes of the reservoir as found by the current survey. The annual losses of capacity of 0. 83 per cent and 0. 62 per cent are comparable, however. It is significant that these two values are of the same order of magnitude.

SEDIMENTATION IN THE RESERVOIR

Summary of Data

Table 1 is a summary of the sedimentation data obtained from this survey of Carbondale Reservoir together with data derived therefrom which are pertinent to the sedimentation problem in this lake. Several of the significant findings shown in this summary are:

1. At the present spillway crest elevation, the 144-acre surface area of the reservoir is the same as when the reservoir was constructed.
2. The capacity of the reservoir for water storage has been reduced from 1386 acre-feet to 1193 acre-feet, or 13. 94 per cent.
3. The sediment accumulation in the lake represents an average annual rate of sediment production of 215 cubic feet per acre from the watershed.

One of the outstanding facts to be noted from Table 1 is the relationship of the original capacity of the reservoir to the watershed area. The original capacity - watershed ratio (C/W ratio) was 462 acre-feet per square mile for the Carbondale Reservoir. In other words, the reservoir was designed and constructed to furnish 462 acre-feet of storage space for every square mile of drainage area in the watershed. Sedimenta-

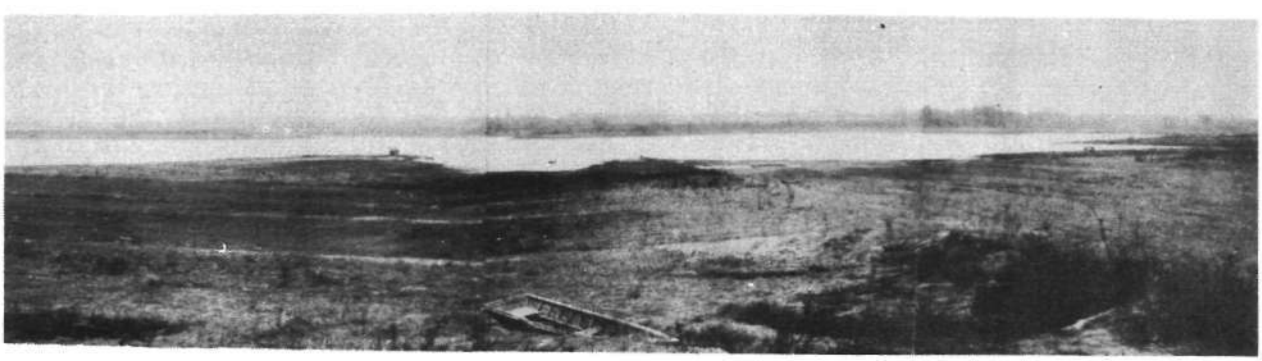

Figure 7. Exposed reservoir bed during drought of 1930.

Table 1

Summary of Sedimentation Data on
Carbondale Reservoir
Carbondale, Illinois

	Quantity	Units
Age[1]		
1926-1948	22. 1	Years
Watershed		
Total area[2]	3. 10	Square miles
	1981.	Acres
Reservoir		
Area at spillway level		
1926	144.	Acres
1948	144.	Acres
Storage capacity at spillway level		
1926	1386.	Acre-feet
	453. 2	Million gallons
1948	1193:	Acre-feet
	389. 9	Million gallons
Capacity per square mile of drainage area[2]		
1926	462.	Acre-feet
1948	398.	Acre-feet
Sedimentation		
Total sediment		
1926-1948	193	Acre-feet
Average annual accumulation		
From entire drainage area		
1926-1948	8.8	Acre-feet
Per square mile of drainage area[3]		
1926-1948	3.05	Acre-feet
Per acre of drainage area[3]		
1926-1948	208.	Vol. cubic feet
By weight4		
1926-1948	7.68	Tons/acre
Depletion of storage		
Loss of original capacity		
Per year		
1926-1948	0.63	Per cent
Total		
1926-1948	13.94	Per cent

1. Storage began in August, 1926; date of survey, September, 1948.
2. Including area of lake.
3. Excluding area of lake.
4. Based on 13 volume-weight samples taken in 1947; average density of sediment, 74. 0 pounds per cubic foot.

tion studies in Illinois and in other parts of the country[6] have shown that the original C/W ratio of a reservoir is significant in determining the trap efficiency of a reservoir. With a given unit rate of sediment production a low capacity reservoir on a large watershed area will lose capacity much faster than a high-capacity reservoir on a small watershed.

It can be seen in Table 2 that the C/W ratio of Carbondale Reservoir compares very favorably with four other reservoirs in the State that have been recently surveyed. The annual loss of capacity in per cent is also in line with these same reservoirs. Figure 8 shows a comparison of the annual loss in capacity in per cent for these same reservoirs.

Distribution of Sediment

The greatest loss of capacity of the reservoir is in the upper end beginning with range 023-022. Figure 9 shows the cross-section along this range with the relative amounts of silt and water. The thickest silt depth measured was

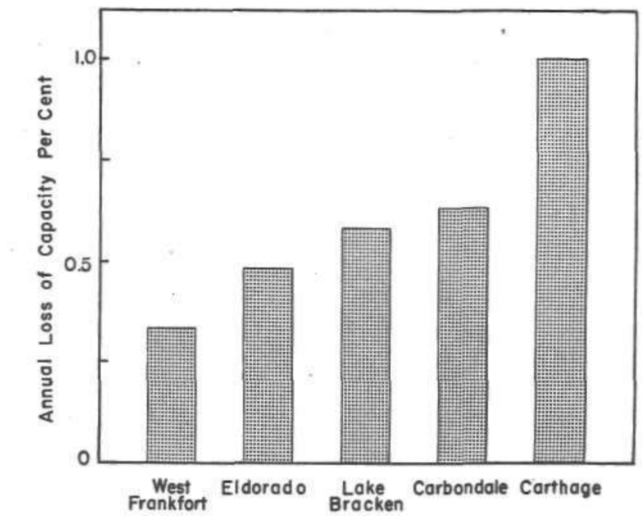

Figure 8. Carbondale Reservoir storage loss compared to other Illinois reservoirs.

Table 2

Sedimentation of Carbondale Reservoir Compared to Other Illinois Reservoirs

	Carbondale Reservoir	Eldorado Reservoir	Carthage Reservoir	West Frankfort Reservoir	Lake Bracken, Galesburg
Watershed area					
Square miles	3.0	2.23	2.94	4.00	8.91
Original capacity					
Acre-feet	1386	844	406	1608	2881
Million gallons	453	258	133		
Original Capacity-Watershed ratio					
Acre-feet/square mile	462	453	138	424	323.4
Age when surveyed					
Years	22.1	29.0	23.4	22.9	25.6
Total loss of capacity					
Per cent	13.9	14.0	24.1	7.5	14.9
Annual loss of capacity					
Acre-feet	8.8	4.1	4.2	5.3	16.8
Million gallons					
Per cent	0.63	0.48	1.03	0.33	0.58
Annual rate of sediment production					
Cubic feet/acre	215.	148.8	99	102	132.6
Tons/acre	7. 9	4. 98	2.47	2. 5	3. 45

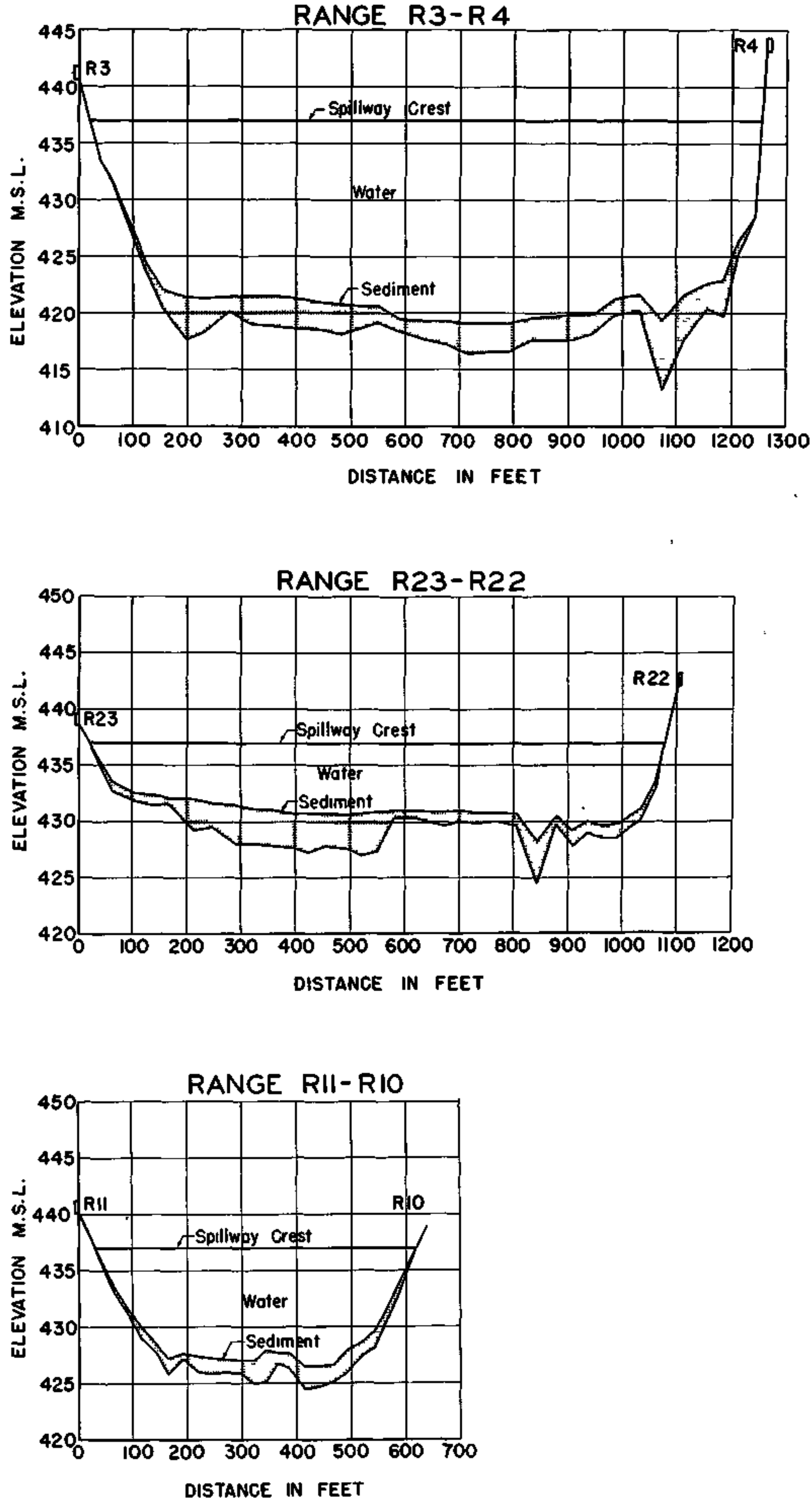

Figure 9. Typical cross-sections, Carbondale Reservoir.

3.8 feet in the original channel. At this section there has been a loss of 21.8% of the original capacity. On range 025-024, the thickest silt depth was 4.6 feet and the capacity loss amounts to 29.3% and on range 027-026 a maximum of 3.1 feet of silt was measured, and the total capacity loss amounts to 22. 5%. The storage capacity of this portion of the reservoir has been reduced by approximately 25%. In the tributary beginning with range 07-09 and going upstream the greatest silt depth measured was 3. 9 feet, and the storage capacity has been reducedby approximately 16%. In the main body of the reservoir starting at the dam and going upstream to range 021-020, the greatest silt depth measured was 5. 8 feet on range 02-01 in the old stream channel, with an average of 2.0 feet of silt deposited across the range. The silt depth decreased in going upstream, the maximum measured on range 020-021 was 3.9 feet, with an average of 1.3 feet across the range. The loss in storage capacity in this portion of the reservoir averages approximately 12%. The three ranges inFigure 9 are typical of the silt distribution in the reservoir, and it can be seen that the original bottom has been covered rather uniformly.

HISTORY OF THE CARBONDALE WATER SUPPLY

Period 1897-1925

A public water supply was first installed at Carbondale about 1897 by private capital. Water was obtained from two wells which were 416 feet and 200 feet deep respectively. By 1915, three additional wells had been put into service. In 1921 the maximum total output from all five wells was 120 gallons per minute or 170, 000 gallons per day. Water from this system of wells was characterized by its very high mineral content and moderate hardness.

Because of the inadequacy of this water supply to furnish the entire needs of the growing city, a citizens committee was formed about 1922 to study plans for a better supply. This committee, consisting of city officials as well as representatives of civic clubs and other interested citizens, enlisted the aid of consulting engineers, P. B. Wilson (Marion) and L. A. Day (St. Louis) in analyzing the problem.

After considering various proposals, including several sites for a surface impounding reservoir, it was recommended that a reservoir be constructed on Piles Fork about three miles south and west of town.

1925 to Present

In September 1925, construction was begun on the present Carbondale reservoir on Piles Fork and on the filter plant. The first water was impounded in the lake in April 1926. At this time the distribution system was also purchased from the private interests. An independent water commission was formed, which owned and operated the public water supply until 1933, when the City of Carbondale undertook the operation of the entire water supply. Since 1933 the water supply has been operated under the jurisdiction of the municipal government.

Increase in Water Consumption

Filter plant records of the daily raw water pumpage from the Carbondale Reservoir are available since 1931. The yearly averages of pumpage have been plotted in Figure 10. In 1931 the average daily pumpage for the year was 686, 000 gallons; by 1948 this had increased to 1,213,000 gallons. The future trend in water consumption is dependent on many factors, such as the rate of growth of population in the city, the possibility of new industries locating in the city, the presence andpossible expansion or reduction of industry in the city, the use of water for new purposes by present users, and the availability of an adequate supply. The future demand will consequently be predicted most accurately on a basis of full knowledge of these matters. The extrapolation shown in Figure 10 is obtained by taking the maximum average pumpage as shown for the year 1949, and computing the daily per capita consumption, which amounts to 108 gpd/c. The population is taken from Figure 11. The extrapolated population line was drawn to correspond to the rate of increase that has taken place in the past for each of the communities shown. Since the total pumpage increase in 1949 was about four times the increase in the previous year, and since there has been a general increase through the past 10 years over that of the preceding 10 years, it might be rightly assumed that for the succeeding years there will be a similar increase in total annual pumpage. This total annual pumpage has been estimated for the future by using the estimated population and the

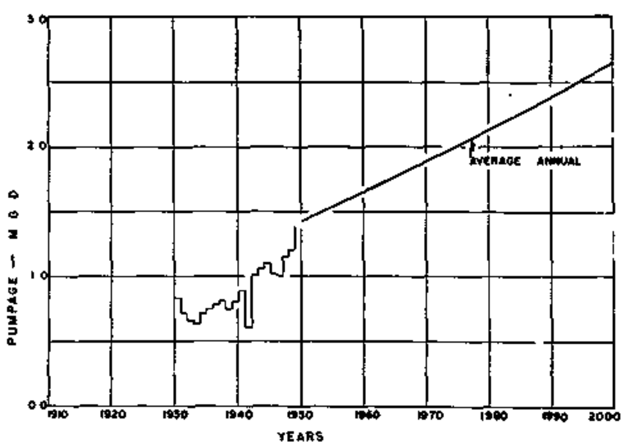

Figure 10. Carbondale water consumption.

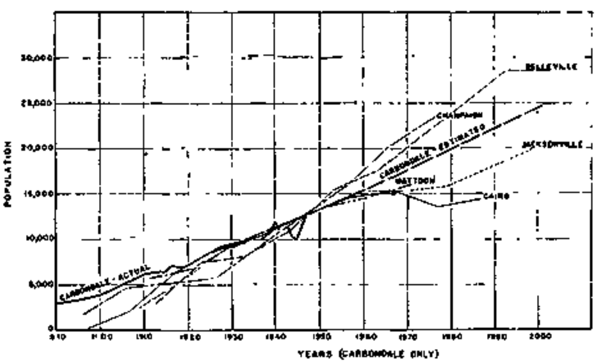

Figure 11. Carbondale population trend.

present daily per capita consumption. The daily per capita consumption from 1948 to 1949 showed an increase from 92 to 109 gallons. This may be slightly in error due to errors in estimating the population. Although the assumed value of 110 gpd/capita used to predict the annual pumpage may be high, it is well to be on the safe side in predicting requirements for the future. Using the estimated population, the average pumpage should be 1,700,000 gallons in I960, and 1,950,000 gallons in 1970.

There does remain then the possibility of increasing per capita water consumption even above the 110 gpd. that has been assumed. This is an additional factor which would tend to increase the future water requirements of the city. The future need as shown in Figure 10 does not include any future increase in per capita consumption, since per capita consumption in a community is not necessarily a function of the population, but is dependent on the character and requirements of the water users.

RESERVOIR OPERATION AND NEED

General

The function of any water supply impounding reservoir.is to store run-off from the watershed during periods when the stream flow exceeds the consumption. The water thus stored is available for use during dry periods when the flow of water in the stream is insufficient to furnish the users' needs. Consequently, to obtain the full value from a reservoir, it should be located on a drainage area of sufficient size that the run-off coming into the reservoir is large enough to exceed the consumption plus the losses. The storage volume of the reservoir should be large enough to fulfill all needs during the driest season for which it is designed.

The best indication of the usefulness and the necessity for a water-supply reservoir is the fluctuation of the water level in the lake. Every time the water level is drawn down in the reservoir, demand is exceeding the inflow. This means there would be a water shortage if the lake were not present. Likewise, the best indication of the impending inadequacy of a reservoir is the occurrence of serious drawdowns during dry periods when inflow is small and consumption is large. Sediment deposits steal needed storage space. This loss of water storage capacity causes increasingly heavy drawdowns during dry periods.

In 1931, four years after the reservoir was filled, the City of Carbondale was faced with a shortage of water. The low stage of the reservoir was due to the second lowest average rainfall in the year 1930 that had been recorded in 52 previous years. Records indicate that every 10-15 yearsthe average rainfall is approximately 10-15 inches below the average of 40 inches. Each of these dry years has been preceded and succeeded by years of average amounts of rainfall.

In 1941 the city was imperiled again, and this time the situation was even more critical than in 1931. The total precipitation on the watershed for 1940 and 1941 was 32. 90 inches and 34.13 inches respectively, both below the annual average of 40 inches for the southern division of the state.

In 1931 Mr. W. D. Gerber, Engineer of the State Water Survey, recommended that the city investigate two possible new reservoir sites, one on Indian Creek and a second on Cedar Creek, that could be used for a supplementary supply. No action by the city was taken. In 1941 the stage of the reservoir got so low that the city was unable to obtain any water for its use. Corrective measures were taken for an additional supply.

Expedient Measures, 1941

On June 7, a 6-inch pipeline was started to Thompson Lake. Salvaged pipe was used and was laid on top of the ground. Water from Thompson Lake supplemented that pumped from the city reservoir. On June 13, permission was obtained to lay a pipeline to Crab Orchard Lake for additional supply if needed. Seventeen thousand feet of 12-inch and 14-inch cast iron pipe, costing $35,000, was purchased, and the laying of the line began August 1. Right-of-way cost $125 per year and the cost of laying the pipe amounted to $6, 970. The total cost of this project was approximately $50,000. The 14-inch pipe was laid to a point one mile west of the Crab Orchard dam and the flow was by gravity. A pump was located here and the water pumped through a 12-inch pipe to the city filter plant. The cost to the city of the water pumped from Crab Orchard was two cents per thousand gallons. After installation of the pipeline, water was pumped for 30 days and also for a week in December 1941. Permission was granted Carbondale to use water from Crab Orchard under the condition that this use be restricted to periods of necessity. It was again necessary to pump from Crab Orchard for a period of 10 days in February 1942.

Drawdown Data

Monthly water level measurements based on the permanent spillway crest are available for Lake Carbondale from 1931 through 1932 and weekly thereafter to the present time. These levels are shown in Figure 12. During this time the largest drawdown occurred in September 1941, when the lake level was 15. 17 feet below the spillway crest. Starting June 15, 1941, the city supply was obtained from other sources and pumping from the lake did not start again until November 1, 1941. The lake was completely drained in October and refilling began after a rain on October 27. The lake level rose until a maximum level of 0. 07 foot above the spillway crest level was reached on May 6, 1942. It was estimated that less than 5 million gallons were discharged for this period. In 1943 the level was above spillway crest twice and 83 million gallons are estimated to have discharged over the spillway. In April 1944, for two days, the level was -0.01 feet above spillway crest, and was down to 8. 69 feet below spillway crest in December 1944. In February 1945, the level was 9. 89 feet below and went to a high of -0. 37 on March 30.

After each low point of the lake level which has been occurring every two years, there has always been rather rapid recovery. For example, March 30, 1945, the level was up to 0.37 foot above crest; April 13, 1948, it was 0.07 foot above crest. It was again above crest in January 1949 and then fell continuously to the low in September 1949.

REMAINING USEFUL LIFE OF RESERVOIR

The original capacity of the lake at spillway crest was shown earlier in this report to be 1386 acre-feet. A shortage of rainfall in any one year greatly reduces the quantity of water available in the reservoir. If the rainfall is considerably below the average for two years running, as was the case in 1940-1941, the available supply of the reservoir will be definitely inadequate. In 1941 the average daily pumpage was 741,000 gallons; in 1949 the estimate was 1,361,000 gallons per day, which is more than an 80% increase in the daily requirements. Therefore, a deficiency in rainfall of 10 or more inches from the mean average for one year will probably result in a shortage of available water from 1950 on, even if the demand does not increase over that in 1949. Moreover, it has been estimated that the daily consumption is going to increase due to the anticipated population increase for the future. This then, in itself, will cause the present reservoir to be inadequate as a dependable municipal supply for the future. "The ratio of reservoir surface area and storage capacity is significant particularly from the standpoint of evaporation. Carbondale reservoir is rather low in this respect and for this reason the losses fromevaporation are high, and with consumption high also, the water level in the reservoir is readily lowered in times of low precipitation. "[7]

The storage capacity of Lake Carbondale is being reduced by 0. 63 per cent per year, which is not excessive. The pumpage in 1941 during the worst drought period in the past completely emptied the reservoir. With the demand increasing and storage capacity decreasing the storage will become more inadequate at a future date.

During the drought of 1940-1941 the total precipitation provided an average daily inflow of 390, 000 gallons in 1940, and 543, 000 gallons in 1941.

In 1950 the capacity of the reservoir is 384, 300, 000 gallons. If it is assumed that an average minimum inflow of 142,400,000 gallons should again occur, the amount of water available for use in such a year would be 526,700,000 gallons. In 1950 it is estimated that the annual pumpage plus evaporation would amount to 637,-660, 000 gallons. It can readily be seen that a

7. Gerber, W. D. , Drought of 1930 and Surface Water Supplies in Illinois. American Water Works Association Journal, Vol. 24, June 1932.

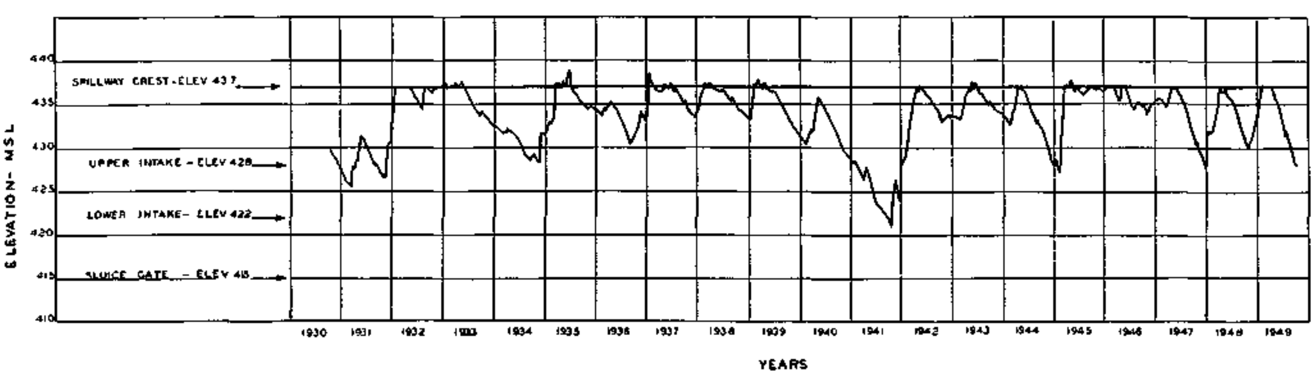

Figure 12. Water level fluctuations, Carbondale Reservoir.

shortage of 111,000,000 gallons would exist. After 1950, the capacity of the reservoir will continue to decrease, and the annual demand is expected to increase. It can also be anticipated that the reservoir will not be full at the beginning of a 12-month period since it is possible again to have a deficiency of precipitation for two consecutive years, such as occurred in 1940-1941, which would cause a greater shortage than has just been discussed. In Figure 13 is shown the relationship between reservoir capacity and pumpage requirements for one-month, three-month, six-month, and one-year periods. It can be seen that annual pumpage requirements at any time after 1940 can cause a shortage of supply and is not dependent on the loss of capacity of the present reservoir. The maximum 6-month requirements will be critical in 1967 as the capacity of the reservoir is decreased due to siltation. One- and three-month pumpage requirements will not be affected by a loss in capacity of the reservoir for another 50 years.

The period demands from Carbondale reservoir as shown in Figure 13 do not include the evaporation factor. Figure 14 was prepared with the evaporation factor added to the anticipated demand. This shows that the reservoir capacity in 1950 will not be sufficient to supply the 6-month demand and that by 1986 the reservoir capacity will be insufficient to meet the 3-month demand of pumpage plus evaporation. The decrease in reservoir capacity as shown is due to siltation.

Although the Carbondale reservoir has been able to furnish an adequate supply, except for the period in 1941 which has been previously discussed, there have been other years, namely 1930 and 1945, when the reservoir level dropped considerably and caused temporary anxiety.

It can be said then that the reservoir capacity never was sufficient to take care of a drought for two consecutive years. Again the years of 1940-1941 are evidence of this.

ECONOMIC LOSS FROM SEDIMENTATION

Lake Carbondale is reported to have cost the taxpayers a total of $74,000 in 1933 when it was purchased from the private utility. Since this survey shows the original capacity of the reservoir to be 1386 acre-feet, it is seen that this storage thus cost originally $54 per acre-foot. The present survey also shows that 8. 8 acre-feet of storage capacity are being lost per year to sediment. At this rate, the loss amounts to $475 of the original investment lost per year.

Replacement of this lost storage capacity as well as the building of additional facilities at present prices would be expensive. In 1926, when Lake Carbondale was constructed, the general cost of such work was much less than at present. In 1933, at the time the lake was purchased, general construction costs were even lower than in 1926. One of the most widely used indices of such construction cost is the Engineering News-Record Construction Cost Index, which is computed monthly and considers current prices of certain basic construction commodities such as cement, steel, labor, etc. In

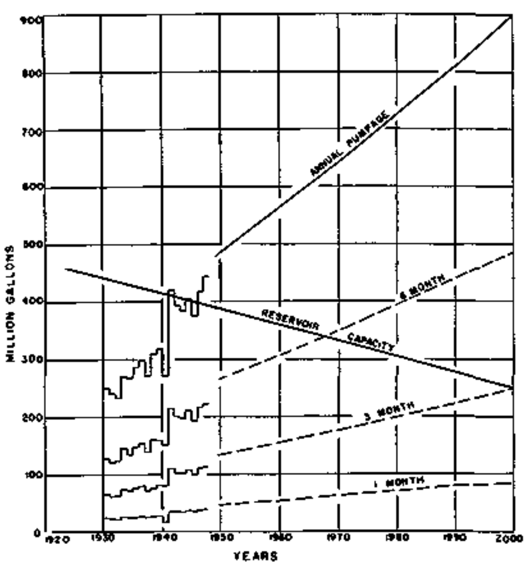

Figure 13. Reservoir capacity and pumpage requirements.

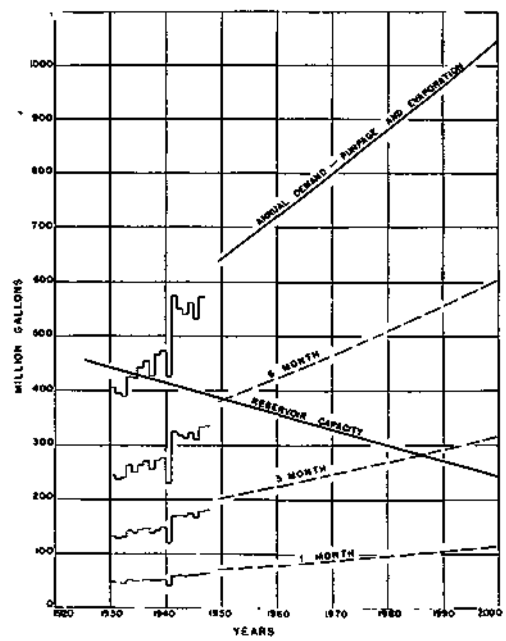

Figure 14. Reservoir capacity and expected total demand on the reservoir.

1926 the Construction Cost Index was 210 (based on the year 1913 = 100).[8] By 1933 this index had fallen to 180, and in 1950 this index had risen to 509. In consideration of this increase in cost the 8. 8 acre-feet of Lake Carbondale storage capacity lost annually would cost $ 1, 330 to replace at the present time. Applying the same increase in cost figures to the total cost of the reservoir, the cost today to build a new reservoir of the same capacity would be $209, 000.

SEDIMENT CHARACTERISTICS

Analyses Made

Sediment samples, taken from several representative locations within the reservoir as shown in Figure 4, were analyzed to determine some of the physical and chemical characteristics of the sediment. These determinations included total organic carbon, total nitrogen, pH, available phosphorus, available potassium, and volume weight analysis. On two samples (No. 4 and 13) base-exchange capacity and total bases were determined as well as particle size fractionations. The data are given in Tables 3 and 4. Where more than one sample was taken in one location, samples were designated A, B and C from top to bottom.

Chemical Character of the Sediment

There is considerable variation in the chemical composition and volume weights of the sediments within the reservoir. In general, the sediment samples taken from the north and west portions of the reservoir (samples No. 1, 2, 10, 11, 12, 13) were hgiher in total organic carbon and total nitrogen, but were lower in volume weight than were sediment samples taken from the south and east portion (samples No. 3, 4, 6, 7, 8, 9) of the reservoir. An inverse relationship should generally exist between the total organic carbon and the volume weight of the sediment samples. This relationship is shown graphically in Figure 15, and suggests that the type of sediments entering the reservoir from the west differs from those entering from the east.

The organic carbon and nitrogen content of the sediment is highest (1. 1 per cent C, and 0. 12 per cent N) in the main body of the reservoir, especially nearest the dam. The lowest nitrogen and carbon contents (0. 52 per cent C, and 0.044 per cent N) are found in the southeast projection of the reservoir. In general, the organic carbon and nitrogen values are lower than that found in most reservoirs. These low values, along with the high sand content in sample No. 4, indicate that most of the fine clay and organic colloids are passing over the spillway. This is to be expected because of the ease with which the colloid materials, found in the eroding soils of this area, may be dispersed.

An analysis of the available elements in the sediment indicates that there are an estimated 5,000 pounds of available potash (K_2O), 6,000 pounds of available phosphoric acid (P_2O_5), and 24, 000 pounds of nitrogen in the approximately 15, 000 tons of sediment that have deposited annually in the reservoir. The potential value of these nutrients, in terms of present fertilizer prices, is in excess of $3,000 per year. This, of course, represents only the potential value of the available nutrients, nitrogen, phosphorus, and potassium, retained in the reservoir; the actual value of the eroded materials lost from the watershed soils would be very much higher.

Physical Character of Sediment

The density of the sediment differs with the location of the deposits in the reservoir. In general, the higher the volume weight, the coarser is the nature of the sediment. Densities vary from a low of 0. 637 (sample No. 1) nearest the dam to 1.37 (sample No. 8) in the southeast projection of the reservoir. This variation would indicate a wide difference in the texture of the sediment within the reservoir, and is substantiated in part by the mechanical analysis of sample No. 4 with over 11 per cent sand, and less than 18 per cent clay, while sample No. 13 contained less than 3 per cent sand and over 23 per cent clay. The fact that sample No. 4, which is located along range 07-08, contains over 11 per cent sand indicates that water movement within the reservoir must be quite rapid.

Similarity of Sediment to Watershed Soils

The similarity of sediments to watershed soils is not too definite. Particle size fractionations were not made on a sufficient number of sediment samples to permit a detailed comparison of the sediments to the principal soil types of the watershed. The most extensive soil types of the watershed are the Ava silt loam, eroded Ava, and Bluford silt loam. The Ava silt loam and its eroded phase are probably the main source of sediment since they occupy the most extensive area. However, it is difficult to relate the sediment in the reservoir to any single soil type because the predominant types are so similar

8. Engineering News-Record, March 29, 1951, Vol. 146, No. 13, p. 121. McGraw Hill Publishing Company, New York, New York.

Table 3

Physical Data on Carbondale Reservoir

Sample No.	Range	Apparent Volume Weight	Sand 50 u %	Silt 50-20 u %	Silt 20-2 u %	Clay 2-0.2 u %	Clay 0.2 %
4	07-08	" 1.27	11.59	43.24	27.80	4.59	12.80
13	022-023	0.974	2.45	33.44	39.32	5.83	17.56

Table 4

Chemical Data on Carbondale Reservoir Sediment

Sample No.	Range	Total N %	Total C %	Base capacity me/100 gm. gm.	Total bases me/100 gm. gm.	Density gm./cc.	pH	Available K an acre lb.	Available P an acre lb.
1A	01-02	0.118	1:10			0.637	6.41	300+	164
1B	01-02	0.070	0.683			0.955	5.84	300+	117
2A	05-06	0.117	1.12				5.43	300+	89
2B	05-06	0.089	0.84				5.56	300+	134
3	07-08	0.051	0.531			1.30	5.80	185	89
4	07-08	0.052	0.546	10.34	7.85	1.27	5.90	224	89
5	07-09	0.090	0.828			1.10	5.36	300+	129
6	011-010	0.057	0.620			1.22	5.74	166	38
7	011-010	0.069	0.725				5.70	260	83
8	013-011	0.044	0.518			1.37	5.00	101	63
9	018-019	0.040	0.515			1.36	5.51	80	120
10A	018-019	0.089	0.900				4.64	292	110
10B	018-019	0.055	0.620			1.40	6.58	216	110
11A	024-025	0.099	0.966			1.17	5.57	300+	126
11B	024-025	0.103	1.03			1.15	5.49	300+	144
11C	024-025	0.093	0.871			1.21	5.30	300+	134
12A	026-027	0.079	0.776			1.19	5.40	96	75
12B	026-027	0.039	0.370			1.32	5.41	40-	41
12C	026-027	0.024	0.265			1.47	5.63	40-	16
12D	026-027	0.030	0.315			1.44	4.70	72	16
13	022-023	0.091	0.978	14.20	8.21	0.974	5.12	300-	100

Table 4a

Chemical Composition of Watershed Soils

Soil Type	pH	Total Exch. bases me/100 gm.	Exch. Cap. me/100 gm.
Ava silt loam	5.7	6.6	11.4
Immature Ava - silt loam	5. 4	4. 9	9.0
Bluford silt loam	5. 4	4. 1	10. 1

in their physical and chemical characteristics. A comparison of the mechanical composition of the Ava silt loam and a Bluford silt loam taken in that general region is given in Table 4. It will be noted that both the pH and the base-exchange analyses of these soils are very similar. This similarity in physical and chemical composition of the watershed soil types makes it impossible to ascribe, on the basis of these analyses, the sediment accumulations in the reservoir to erosion of a specific soil type within the watershed.

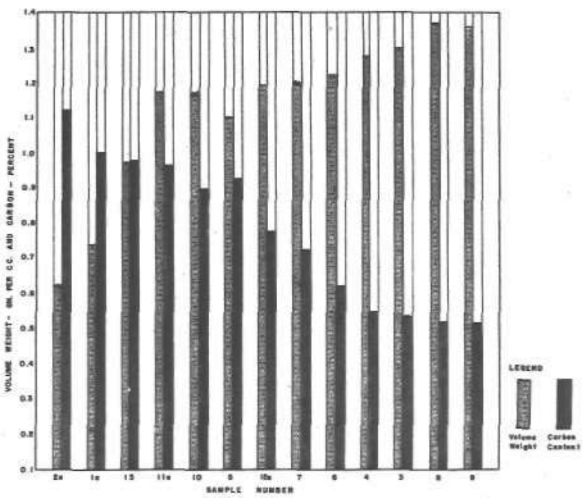

Figure 15. Volume-weight and organic carbon relation for Carbondale Reservoir sediments.

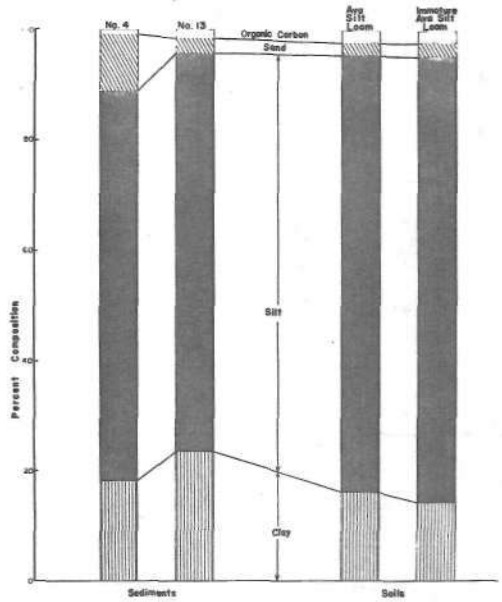

Figure 16. Size distribution of sediment samples compared to watershed soils.

WATERSHED

PHYSIOGRAPHY

The Carbondale Reservoir watershed consists of 1,837 acres or 2.88 square miles within Carbondale and Makanda Townships of Jackson County. It is generally oval in shape and is drained by two main branches of Pikes Fork as shown in Figure 2. It extends generally south and west of the reservoir with its highest point approximately 600 feet above mean sea level in section 7, T. 10 S., R. 1 W., 3rd PM.

The watershed is located on the extreme north slope of the Shawnee Hills section of southern Illinois[9] in the Interior Low Plateaus Province. It consists of ridges maturely dissected by youthful valleys with remnants of flat upland locally preserved on narrow ridge crests modified by a moderately deep loess deposition.

SOIL GROUPS AND LAND CAPABILITY

Three main classes of soils occur in the watershed: light-colored, medium-textured, very slowly permeable soils which extend over 85.8 per cent of the area; light-colored, medium-textured, moderately permeable soils which extend over 3% of the area; bottom-land soils which extend over 11. 1 per cent of the area. In addition, light-colored, medium-textured very slowly permeable, poorly drained soil comprises . 1 per cent of the area. The dominant soil group is the Ava silt loam, which occupies 73. 3 per cent of the entire area. These soils are generally very slowly permeable and highly erosive when cultivated. The watershed soil groups are tabulated in Table 5.

The land capability classes on the watershed are classes II, III, IV, V, VI, and VII, as shown in Table 6. By this classification only one half the watershed is considered suitable for cultivation. About 31.2 per cent of the watershed is class II and III land, which is recommended for regular cropping rotations with supporting erosion control practices. The remaining one half of the land consists of classes V, VI, and VII, which are recommended for pasture and woodland only and are not recommended for any cultivation. Figure 17 shows the general location and distribution of the various land classes in the watershed. For descriptions of these land classes, see Table 6.

9. Leighton, Ekblaw, and Horberg. Physiographic Division of Illinois, Report of Investigation No. 129. State Geological Survey, Urbana, Illinois.

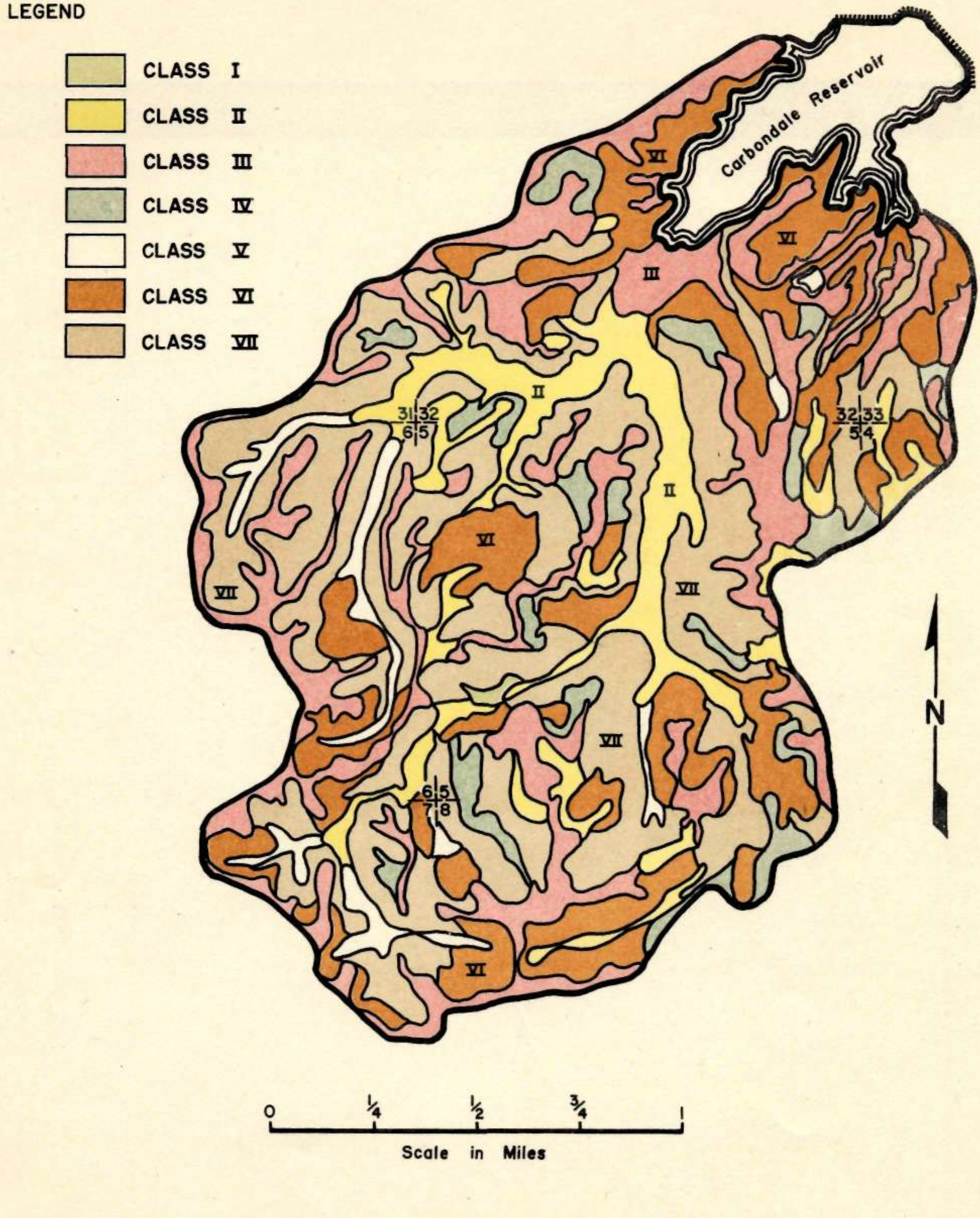

Figure 17. Land Use Capability Map - Carbondale Reservoir Watershed

U.S.D.A., Soil Conservation Service, Milwaukee, 1951

Table 5

Acreages and Percentages of Various Soil Groups
in Carbondale Reservoir Watershed

Soil Group	Area: Acres	Area: Per cent
1. Light-colored, medium-textured, very slowly permeable soils:		
13 Bluford Blair silt loam group	230	12. 5
14 Ava silt loam group	1346	73. 3
Total	1576	85.8
2. Light-colored, medium-textured, very slowly permeable, poorly drained soils:		
12 Wynoose silt loam group	2	0. 1
3. Light-colored, medium-textured, moderately permeable soils:		
Clement silt loam group	55	3. 0
4. Bottomland soils:		
Bonnie silt loam group	45	2. 4
Belknap silt loam group	124	6. 8
Sharon silt loam group	35	1.9
Total	204	11. 1
Entire watershed	1837	100.0

SLOPES

Slopes influence the velocity of run-off and also the rate at which soil erosion occurs. In general, slopes are steep in this watershed. From Table 7 it is shown that 63. 1 per cent of the entire watershed has slopes 7 per cent or steeper, 44. 3 per cent is 12 per cent or steeper and 4. 8 per cent is over 30 per cent. Only 7. 2 per cent falls in the A slope group with 0 to 1 \/l per cent slopes.

PRESENT LAND USE

Probably the most important factor that affects the rate of sediment production from agricultural watersheds is land use. Five classes of land use were mapped in the conservation survey. Cropland is all land on which crops were grown at the time the survey was made. It includes land in row crops, small grains, and hay. Pasture land is land in perennial grasses, and woodland is land which is at least 40 per cent covered by the spread of trees. Miscellaneous land consists of land used for farmsteads, roads, or other purposes, while idle land consists of land not used for cultivation or any purpose for economic return.

The distribution of land use on the watershed in each slope class is presented in-Table 7. Present use of land for cultivation does not follow slopes, as evidenced by the fact that the highest percentage of cropland is in the 4 to 7 per cent or C slope class and a higher per cent of .the 18 to 30 per cent or F slope class is in cropland than the 0 to 1 1/2 per cent or A slope class. However, in the use of land for pasture and woodland, the highest per cent of pasture is found on the 12 to 18 per cent or E slope class and the highest per cent of land used for woodland is found on the 18-30 per cent or F slope class.

Table 6 compares the present land use in relation to the seven land capability classes of the watershed. Of the present cropland, 68. 1 per cent is in classes II, III, and IV, but 31.9 per cent of the cropland is on class Viand class VII, which is not recommended for cultivation. Much of the present pasture and woodland is found in the recommended classes. Fifty-eight and one-tenth per cent of the pasture and 87. 1 per cent of the woodland are in land capability classes V, VI. and VII.

Three hundred eighty-three acres, or 20. 8 per 'cent, of the watershed are listed as idle land. Much of this idle land has been in cropland in the past but is now eroded and depleted

Table 6

Land Capability Compared with Existing Land Use at Time of Survey
Carbondale Reservoir Watershed

Class and Capability	Present Use: Cropland acres	%	Idle Land acres	%	Pasture acres	%	Woodland acres	%	Miscellaneous acres	%	Entire Watershed acres	%
Class I Land Suitable for cultivation, requiring no erosion control practices to maintain soil for general agricultural practices	---	---	---	---	2	0.5	---	---	---	---	2	0.1
Class II Land Good land that can be cultivated safely with easily applied practices	205	26.8	39	10.2	38	9.1	23	9.6	1	8.3	306	16.7
Class III Land Moderately good land that can be cultivated safely with such intensive treatments as terracing or water management	170	21.7	20	5.2	70	16.7	---	---	7	58.3	267	14.5
Class IV Land Best suited to hay or pasture, but can be cultivated occasionally, usually not more than 1 year in 6	154	19.6	112	29.2	65	15.6	8	3.3	2	16.7	341	18.6
Class V Land Suited for grazing or forestry with slight or no limitations; needs only good management	5	---	43	11.3	10	2.4	16	6.6	---	---	74	4.0
Class VI Land Not recommended for cultivation; best suited for permanent pasture	159	20.3	71	18.5	137	32.9	95	39.4	2	16.7	464	25.3
Class VII Land Not recommended for cultivation; suited for woodland or pasture with major restrictions in use	91	11.6	98	25.6	95	22.8	99	41.1	---	---	383	20.8
Entire Watershed	784	100.0	383	100.0	417	100.0	241	100.0	12	100.0	1837	100.0

Table 7

Distribution of Land Use Classes in Each Slope Class
Carbondale Reservoir Watershed

Slope Class	Cropland acres	%	Idle Land acres	%	Pasture acres	%	Woodland acres	%	Miscellaneous acres	%	Total acres	%
A (0 - 1-1/2 per cent)	59	7.5	43	11.2	10	2.4	21	8.7	---	---	133	7.2
B (1 - 1/2-4 per cent)	151	19.3	40	10.5	40	9.6	18	7.5	1	8.3	250	13.6
C (4 - 7 per cent)	208	26.5	20	5.2	60	14.4	---	---	7	58.3	295	16.1
D (7 - 12 per cent)	154	19.6	112	29.2	75	18.0	2	0.8	2	16.7	345	18.8
E (12 - 18 per cent)	129	16.5	77	20.1	168	40.3	19	7.9	2	16.7	395	21.5
F (18 - 30 per cent)	71	9.1	88	23.0	62	14.8	110	45.6	---	---	331	18.0
G (over 30 per cent)	12	1.5	3	0.8	2	0.-5	71	29.5	---	---	88	4.8
Total	784	100.0	383	100.0	417	100.0	241	100.0	12	100.0	1837	100.0

of fertility. Some of the idle land is listed as very severely eroded and destroyed land. There are 204 acres of such land, comprising 11 per cent of the watershed.

The land use history of Carbondale and Makanda Townships for the decade 1938-1947 is shown in Table 8. The percentage of tillable land in corn, soybeans, and cowpeas is nearly as great as that in hay and pasture. In 1947, numerous small fields of corn were found planted in the waterways and along streams parallel to the channels. In 1946 the average farm in this area consisted of 104 acres, of which 57 percent was considered tillable. Thirty-two per cent of this tillable land produced corn, soybeans, and cowpeas, 12 per cent small grains, 34 per cent hay and pasture, and 22 per cent was idle land.

Apparently only a small proportion of the watershed has received soil treatment such as limestone, phosphate, and potash. This lack of treatment means that most of the hay and pasture lands are low in productivity and subject to erosion. It also accounts in part for the high acreage of idle land on which crop failures are common.

EROSION

Both sheet erosion and gully erosion occur in the watershed. In developing any type of watershed treatment program for protection of a reservoir against silting, it is of primary importance to know the source of the sediment.

The distribution of erosion groups in each land use class is given in Table 9. The following erosion groups were mapped:

0. No apparent erosion. To be used where the approximate original depth of topsoil still remains. (This is not restricted to level land).

1. Slight to moderate erosion. Over seven inches of original topsoil remaining, no subsoil exposed by plow.

2. Moderately severe erosion. Occasional to frequent exposure of subsoil by plow, three to seven inches of topsoil remaining. Small areas of "1" erosion and "3" erosion, too small to delineate, may be tolerated.

3. Severe erosion. Erosion of the subsoil, less than three inches of surface soil remaining. The texture and color of the soil will be largely that of subsoil, because of the large proportion of the mixture being subsoil.

4. Very severe erosion. Frequent gullies, too deep to cross with farm implements (less than 100 feet apart). Very severe sheet erosion that has penetrated into parent material may also be included in this group.

5. Destroyed land. Very frequent or large gullies. Destroyed for general agricultural purposes. Over 75% of the delineated area in gullies.

Erosion by sheet wash and by gullying or channel flow were mapped separately during the course of the conservation survey. Deposition

Table 8

Average Land Use, Carbondale and Makanda Townships, Jackson County, Illinois, 1938-1947[a]

Items	1938	1933	1940	1941	1942	1943	1944	1945	1946	1947[b]
Acres per farm	92	87	94	97	96	101	109	101	104	
Per cent of farm tillable	72	75	71	58	60	60	60	58	57	
Per cent tillable land in:										
Corn	15	13	14	18	16	17	19	14	24	21
Soybeans and cowpeas	7	8	10	13	12	13	10	8	8	10
Small grains	8	8	6	11	10	7	11	11	12	8
Hay and pasture	42	47	44	37	44	46	41	33	34	35
Other and idle	28	24	26	21	18	17	19	34	22	26

a. Based on assessor's acreage census.
b. Preliminary data.

on flood plains and in channels was also identified.

Calculations on soil removal by deep gullying on the watershed show that only 9.2 acre-feet of silt have been produced in this manner. Similar calculations show that 12.5 acre-feet of soil have been deposited in the channels and on small flood plains above the reservoir. It is further estimated that more than 500 acre-feet of soil have been removed from the watershed by sheet erosion and shallow gullying.

From these measurements it is estimated that over 90 per cent of the eroded material has come from sheet erosion. Watershed treatment for reduction of the rate of sedimentation must therefore be concentrated on the areas subject to severe sheet erosion and used as cropland or idle land previously cropped.

Figure 18 shows the percentage of the various erosion classes in the watershed. The distribution of these erosion groups in each slope class is given in Table 10. The greatest quantity of severe erosion is found on D, E, and F slopes ranging from 7 to 30 per cent.

Table 9 presents the distribution of erosion groups in each land use class. Only 82 acres of cropland are subjected to no apparent erosion, 214 acres are subject to slight to moderate erosion, 152 acres are subject to moderately severe erosion and 249 acres are subject to severe erosion. Over one half the watershed, 935 acres, is subject to moderately severe and severe erosion. Of this, 401 acres are in cropland and 228 acres are idle. A high proportion of the silt has come from this latter area.

Table 10 shows the distribution of erosion groups in each slope class. It is evident that severe erosion has occurred principally on C, D, and E slope groups. Thus the extent of erosion is correlated with slope, particularly in the case of cropland.

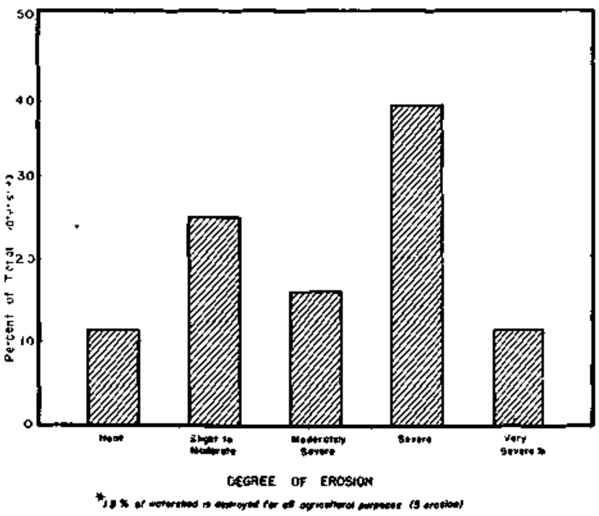

Figure 18. Per cent of erosion classes in watershed.

SOIL CONSERVATION

Application of soil conservation practices is needed on all cultivated, pasture and woodland of this watershed to achieve maximum reduction of erosion and sedimentation.

One of the major needs on the watershed is land use adjustment. Two hundred fifty acres of land now cropped are so steep and eroded as to be classed in land classes VI and VII. This land should be shifted to pasture and woods. This is also true of 200 acres of idle land in the same land capability classes. These 450 acres now cropped or idle account for a large proportion of the erosion. By soil treatment, seeding pasture mixtures, controlled grazing on the pasture land, planting suitable trees and providing protection against fires and grazing on the woodland, erosion can be reduced to a negligible quantity. In turn, 170 acres of idle land in classes II, III, and IV may be used for cropland with proper rotations, soil treatment and contour farming, grass waterways and terracing. At present there is very limited use of contour farming, terracing and other supporting conservation practices on the cropland of the watershed.

Application of slope and practice limitations[10] to the watershed as indicated by the 1947 surveys and the land use history since 1938, shows an average annual soil loss by erosion of 21,242 tons from the watershed. (Table 11.)

After needed land use changes, described above, are made and an intensive conservation program is applied to the cropland similar computations by slope and practice limitations show that erosion losses may be reduced to 1750 tons or about one acre-foot annually for the entire watershed. (Table 12.) The application of the above measures would thus reduce the soil loss from the watershed by more than 90 per cent.

To achieve the above results all cropland in land classes II, III, and IV would require contour farming and terracing. Rotations with legumes and grasses on 50% of the class II and III land and 75% of the class IV land would also be required.

In addition, pasture land would receive needed soil treatment and controlled grazing, and woodland would be protected. Control of active gully heads by sod, tree planting, and gully control structures would also be required.

It should be noted from Tables 9 and 10 that application of the conservation program described above would reduce total cropland by only 21 acres and increase pasture land by 283 acres and woodland by 118 acres. Use of idle land would account for a large part of this increase.

---

10. Van Doren, C. A. and Klingebiel, A. A., Slope and Practice Limitations for Illinois (mimeographed).

Technical assistance to landowners and operators on the watershed in applying the conservation program is available through the Jackson County Soil Conservation District established in 1944. Payments which would assist in applying conservation practices are also available through the Production and Marketing Administration.

Table 9

Distribution of Erosion Groups in Each Land Use Class
Carbondale Reservoir Watershed

Land use class	No apparent erosion		Slight to moderate erosion		Moderately severe erosion		Severe erosion		Very severe erosion		Destroyed land		Total
	acres	%	acres	%	acres	%	acres	%	acres	%	acres	%	acres
Cropland	82	39.2	214	43.8	152	59.1	249	36.7	75	41.9	12	48.0	784
Idle land	59	28.2	46	9.4	31	12.1	197	29.1	37	20.7	13	52.0	383
Pasture	34	16.3	67	13.7	44	17.1	207	30.5	65	36.3	--	----	417
Woodland	34	16.3	160	32.7	20	7.8	25	3.7	2	1.1	--	----	241
Miscellaneous	--	----	2	0.4	10	3.9	---	----	---	----	--	----	12
Total	209	100.0	489	100.0	257	100.0	678	100.0	179	100.0	25	100.0	1837

Table 10

Distribution of Erosion Groups in Each Slope Class
Carbondale Reservoir Watershed

Land use class	No apparent erosion		Slight to moderate erosion		Moderately severe erosion		Severe erosion		Very severe erosion		Destroyed land		Total acres
	acres	%	acres	%	acres	%	acres	%	acres	%	acres	%	
A (0 - 1-1/2%)	133	63.6	---	----	---	----	---	----	---	----	---	----	133
B (1-1/2 - 4%)	74	35.4	172	35.2	4	1.5	---	----	---	----	---	----	250
C (4 - 7%)	---	----	113	23.1	129	50.2	17	2.5	36	20.1	---	----	295
D (7 - 12%)	1	0.5	12	2.4	76	29.6	256	37.8	---	----	---	----	345
E (12 - 18%)	---	----	6	1.2	19	7.4	293	43.2	77	43.0	---	----	395
F (18 - 30%)	1	0.5	124	25.4	11	4.3	112	16.5	58	32.4	25	100.0	331
G (over 30%)	---	----	62	12.7	18	7.0	---	----	8	4.5	---	----	88
Total	209	100.0	489	100.0	257	100.0	678	100.0	179	100.0	25	100.0	1837

Table 11

Soil Losses without Conservation Program
Present Condition of Watershed

Slope Group	Land in Cultivation		Idle Land		Pasture		Woodland		Total annual soil loss in tons
	acres	annual soil loss (tons)	acres	annual soil loss (tons)	acres	annual soil loss (tons)	acres	annual soil loss (tons)	
A (0 - 1-1/2%)	59	142	43	0	10	0	21	0	142
B (1-1/2 - 4%)	151	726	40	88	40	0	18	0	814
C (4 - 7%)	208	2,080	20	100	60	3	0	0	2,183
D (7 - 12%)	154	3,390	112	1,232	75	15	2	0	4,637
E (12 - 18%)	129	5,160	77	1,540	168	84	19	2	6,786
F (18 - 30%)	71	3,550	88	2,200	62	62	110	23	5,835
G (over 30%)	12	720	3	90	2	0	71	35	845
Total	784	15,768	383	5,250	417	164	241	60	21,242

Table 12

Soil Losses with Conservation Program

Slope Group	Land in Cultivation		Land in Pasture		Woodland		Miscellaneous Use		Total annual soil loss in tons
	acres	annual soil loss (tons)	acres	annual soil loss (tons)	acres	annual soil loss (tons)	acres	annual soil loss (tons)	
A (0 - 1-1/2%)	133	400	0	0	0	0	0	0	400
B (1-1/2 - 4%)	250	225	0	0	0	0	0	0	225
C (4 - 7%)	230	484	60	6	0	0	5	0	490
D (7 - 12%)	150	450	190	19	0	0	5	0	469
E (12 - 18%)	0	0	300	50	90	10	5	0	60
F (18 - 30%)	0	0	150	45	181	36	0	0	81
G (over 30%)	0	0	0	0	88	25	0	0	25
Total	763	1,559	700	120	359	71	15	0	1,750

REMEDIAL MEASURES

Practicability

This sedimentation survey reveals that Carbondale Reservoir is losing capacity at a rate of 0.63 per cent per year, which is not considered exorbitant. The hydrologic study of rainfall and run-off in the area shows that the reservoir was adequately designed as regards sedimentation. The total capacity of the reservoir was just adequate to furnish the needs of the city at the time of construction. It has already been proven (in 1940-1941) that increasing water supply needs are so great that already the reservoir is inadequate to furnish the needs of the city during a prolonged drought. This inadequacy must be attributed not directly to the sedimentation in the reservoir, but also to inadequate total storage.

The need for enlarging the present storage facilities or finding a new source of water supply is of concern to the city. To accomplish this, consideration might be given to raising the dam or developing another reliable water source. The relative feasibility of these measures can be determined only by a thorough engineering investigation.

The provision of a water supply adequate to meet the entire needs of the growing city is a requisite for the normal economic development of the city. A city with a limited water supply is a city of limited growth. The present arrangement whereby Crab Orchard Lake is used as an emergency supply for Carbondale appears satisfactory for the time being. Increasing industrial development in the Crab Orchard area, however, will lead to increased industrial pumpage from Crab Orchard Lake. During the critical period of drought, the Crab Orchard supply itself may be greatly needed by others at the exact time that Carbondale might expect to take water from this lake.

The volume of water in Crab Orchard Lake which can be guaranteed to be available for industrial use during the drought periods is certainly lessened by the dependence of the City of Carbondale on this lake. This fact would naturally lead the lake authorities to discourage use of this lake by the city so that industrial expansion can be encouraged. The increase in industry located in the Crab Orchard area would tend to increase the population of Carbondale as more people moved into the region. Thus the water supply situation in the entire region is interconnected and is an important factor in determining the economic development of the region. If a water supply sufficient to meet the increasing needs of the City of Carbondale could be developed independent of Crab Orchard Lake, it would be afurther step ahead in the development of both the city and the entire region. The protection and improvement of the essential public utilities of the area, including the water supply, demand the highest of civic responsibilities. Successful public ownership of such utilities is contingent upon the recognition of this fact by public officials, the acceptance of responsibility for needed actions, and the orderly development of the resources of the area in accordance with a long-range plan.

Raising the Dam

One of the first measures usually considered when it becomes necessary to provide additional reservoir storage space is the raising of the present dam and spillway. In many cases such action can provide the additional storage necessary to postpone the water shortage. At Carbondale a water shortage has already occurred and can be expected to occur in greater severity at any time. The increased storage necessary is greater than can be provided by a raise in the spillway. In addition, the adequacy of the present drainage to supply a larger reservoir is very questionable, since the present reservoir is below crest much of the year. The water levels shown in Figure 12 illustrate that spillage occurs very infrequently even at present spillway elevation.

Other Possible Reservoir Sites

Two new reservoir sites can be considered for use by Carbondale. The first of these is that of Indian Creek as shown in Figure 19. A dam constructed across Indian Creek near its confluence with Drury Creek could produce a lake with a surface area of 525 acres at an elevation of 420 feet, or 323 acres at 410 feet. This lake would have a drainage area of 10.07 square miles and a volume of 2690 acre-feet or 880 million gallons. The C/W ratio of 267 is highly satisfactory. (In addition to its use as a water supply, this lake might be profitably used for recreational purposes.) Average precipitation with 30 per cent run-off would fill the lake 2 1/2 times each year, and the minimum precipitation 1. 6 times per year. The capacity is almost two times the original volume of the present Lake Carbondale, and the surface area more than two times the present lake.

Two ways could be used to bring water into the filter plant:

1. Pump water into Piles Creek reservoir and allow it to go through the present pipeline.
2. Construct a new pipeline from Indian Creek to the plant.

The estimated cost of this reservoir at present prices is roughly $340,000.

The second reservoir site that can be considered is that of Sycamore Creek which is also shown on Figure 19. A dam located as shown would produce a lake with a surface area of 237 acres at an elevation of 420 feet. This lake would have a drainage watershed area of 5. 55 square miles and a volume of 3, 160 acre-feet of 1033 million gallons. The C/W ratio of 570 is very satisfactory. Average precipitation at 30% run-off would provide enough water to fill the reservoir 1. 2 times per year. A minimum amount of precipitation would fill the reservoir only 0. 8 times per year. This would be a disadvantage for this site inasmuch as the lake capacity would be too large for the size of the drainage area. This water could be brought directly into Carbondale, or a line could be laid to connect to the one that is laid to Crab Orchard

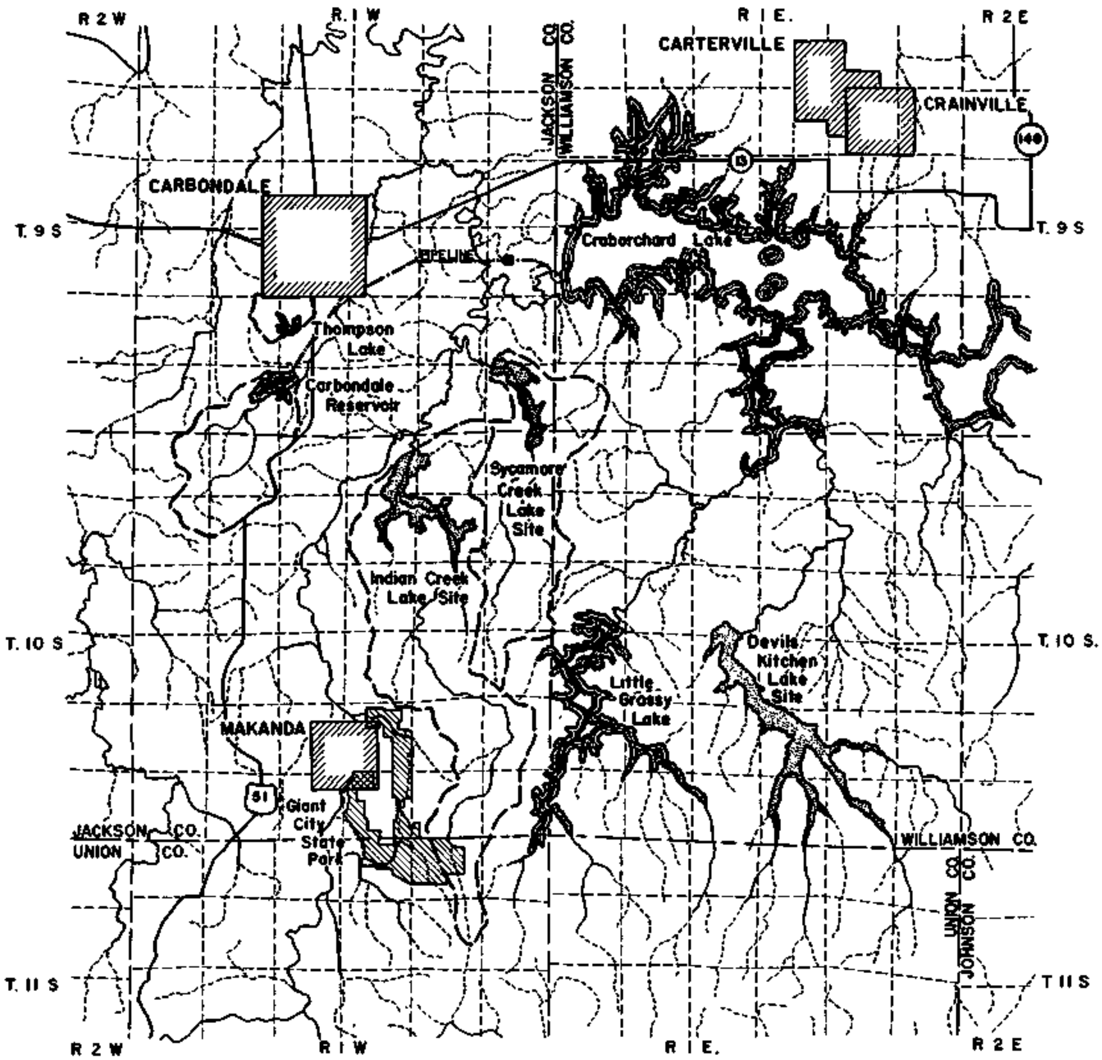

Figure 19. Possible reservoir sites in Carbondale area.

Lake. The estimated cost of this reservoir at present prices is roughly $398,000.

Dredging

Some reservoir owners have resorted to dredging to restore reservoir capacity lost by sedimentation. The two limiting factors in this method are the cost and the disposal of dredged material. In the past, dredging has compared unfavorably financially to other methods of providing storage space. Dredging has proved economical only where large shallow areas appear in lakes with very high recreational and esthetic values. At Carbondale it is believed other remedial measures would be more applicable.

Other Measures

Several important supplementary measures for control of sedimentation are discussed in Miscellaneous Publication No. 521 of the U. S. Department of Agriculture entitled, "The Control of Reservoir Silting." Sediment basins, vegetative screens and other measures are discussed. This publication can furnish much valuable help to reservoir owners faced with a sedimentation problem.

Watershed Treatment Program

The rate of sedimentation can be reduced by an estimated 90 per cent as outlined in a preceding section and shown in Tables 11 and 12. The installation of these watershed treatment measures at present will not materially reduce the hazard of a water shortage at Carbondale since the shortage is imminent now. Although this program will not greatly alleviate the water supply problem, it is highly important from the standpoint of preservation of the present reservoir. No matter what additional provisions are made tor water supply, it is probable that the present reservoir will continue in use as the major source of supply. The stopping of sediment in this manner, at the very source, is usually more economical than dredging or the development of additional sorage.

A program of watershed protection could be justified at present for the purpose of extending the period that Carbondale Reservoir can continue to be used in conjunction with other storage.

The control of the watershed area above a municipal water supply is considered so important in many parts of the country that the municipality purchases the entire drainage basin. The land is leased to private parties for agricultural use under the terms of the municipality in order that excessive soil loss is avoided. The operation of such lands by the city is normally profitable in itself in addition to saving the soil. Such measures may not be necessary at Carbondale but should definitely be considered. Perhaps the purchase of only the most critical areas would be necessary. The city could furnish financial aid to the private farmers in establishing conservation and soil-saving measures on the land. This item of watershed protection should be given consideration not only in protection of the present Carbondale Reservoir but in considering new reservoir developments. The items for watershed lands and protection should be considered as a part of the reservoir cost. The purchase, ownership and operation of such watershed lands is considered a rightful field of activity of municipalities in protecting public investments in reservoirs.

11. LaDue, W. R., Reservoir Lands Pay Their Way - Balanced Use of Reservoir Lands. Journal American Waterworks Association, August, 1948.

COSTS AND BENEFITS OF CONSERVATION

Conservation needs in this watershed include fertility improvement, land-use adjustment, rotations using larger acreages of adapted legume - grass mixtures, and erosion control practices. The productivity level and the earnings of farms are comparatively low unless a soil conservation and fertility improvement program is applied. At the present time, approximately 400 acres of the 1,837 acres in the watershed are classed as idle land. The remaining acreage in cropland, pasture, and woods is producing at only about one-half of its possibilities.

While studies of the costs and benefits of conservation have not been made in this immediate area, results of studies in Jefferson County, Illinois, and in Madison and St. Clair Counties, Illinois, are applicable. The study of costs and benefits of conservation in Jefferson County shows the possibilities of increasing farm production and earnings by use of a soil conservation program. In a comparison of farms with a high proportion of conservation applied and farms with little or no conservation, it was found that farms with high conservation had a higher proportion of their acreage in corn and soybeans, small grains, and legume hay and rotation pasture and had less cropland idle. They also had larger acreages of productive permanent pasture and had a timber improvement program under way which would lead to more productive timber production.

The study of costs and benefits of conservation in Jefferson County showed the average costs of applying a conservation program to be $22.63 per acre of the total farm (based on 1945 costs). The high-conservation farms spent 10 per cent of their gross income for conservation. The lower level of soil fertility in this area made the needs for limestone, phosphate, and fertilizer greater in this area than in some other areas of the state. However, this soil fertility treatment plus the use or practices such as contouring, terracing, grass waterways, drainage, etc., resulted in much higher crop yields. On some farms yields of grain and hay crops were more than doubled and pasture production was increased four to five times over that existing before the program was adopted. Livestock production in terms of meat and milk produced was also greatly increased. The average net farm income was $7. 83 an acre a year higher on the high-conservation farms in Jefferson County.

The silt loam soils, which are predominant in the Carbondale Reservoir watershed, are probably more productive than the Jefferson County soils. These soils are good hay and pasture soils and give good response to soil treatment. While the costs of a conservation program in this area would be similar to those in Jefferson County, the benefits from conservation would be greater. Some case example farms near the Carbondale Reservoir watershed on soils similar to those in the watershed serve to illustrate the possible returns from pastures on farms following a complete conservation program: Farm A is producing 429 pounds of beef per acre on alfalfa-brome grass; Farm B had returns of $63. 57 per acre of alfalfa-brome grass fed dairy cattle, while Farm C had returns of $62.96 per acre of ladino clover-brome grass fed dairy cattle (value of grain fed was deducted in computing these returns from dairy cattle on pasture).

Nine years of records on physically comparable high - and - low - conservation farms in Madison - St. Clair Counties show that high-conservation farms had higher crop yields, higher returns per $100 feed fed to livestock, and had net incomes averaging $5.61 per acre per year more as a result of the conservation program.

Cost of a Watershed Program

Low farm earnings and a lack of capital for initiating conservation are major factors limiting the adoption of conservation in the Carbondale reservoir watershed. Using the average cost of $22.63 per acre to establish a conservation program in Jefferson County, it would cost $33,108 to establish a conservation program on the 1,463 acres in the Carbondale Reservoir watershed in cropland and pasture. Using the benefits of a conservation program of $7.83 an acre from the Jefferson County area (costs and benefits taken for the year 1945; the benefits are conservative for the Carbondale area), four years of the increased income would pay the complete costs of establishing the program plus interest charges that might be necessary on capital borrowed to finance such a program. Observations indicate that it might take two to four years from the time a conservation program was started to achieve the increased income from such a program. Thus, at 1945 costs and farm prices the cost of establishing a complete conservation program could be paid in a period of six to eight years. In addition, the capital resources of the farm would be not only maintained but built up, and the farm would be producing at a profitable level.

RECOMMENDATIONS

It is recommended that the City of Carbondale make provisions now for an adequate municipal water supply independent of Crab Orchard Lake in order that the normal industrial and economic development of the city and region can proceed without hindrance.

It is recommended that the City of Carbondale sponsor immediately the development of a soil and water conservation program on Carbondale Reservoir watershed in order to prolong the ultimate life of this reservoir and the length of time it can be used as part of the public supply. This program should be carried out in cooperation with the Jackson County Soil Conservation District and other agricultural agencies and in accordance with the foregoing report.

It is recommended that the City of Carbondale purchase the watershed areas which are critical to erosion control or else assume the major financial responsibility in the application of the needed conservation measures to these areas. In the latter case, financial assistance to present landowners would be contingent upon the landowners agreement to maintain such conservation measures.

REPORTS OF INVESTIGATIONS

ISSUED BY THE STATE WATER SURVEY